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AN OUTDOOR WEARABLE ASSISTIVE SYSTEM POWERED BY CNN FOR BLIND

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Abstract: In this research, we suggest a mobility aid to aid the visually handicapped when they are out and about. The ZED 2 binocular depth camera and the Jetson AGX Xavier embedded system from Nvidia make up this auxiliary device. The picture of the environment in front of the visually impaired user is divided into seven equal parts using the CNN neural network FAST-SCNN and the depth map acquired by the ZED 2. The system calculates a walkability confidence value for each section and then plays a voice cue in the most effective way, allowing a visually impaired person to safely walk down the sidewalk, avoid obstructions, and utilize the crosswalk. Moreover, the YOLOv5s network described by Jocher, G. et al. recognizes the obstruction in the user's path. Finally, we gave a visually impaired individual the suggested assistive device to test out in the area of a Taiwanese MRT station. According to the visually challenged individual, he felt more secure going outside thanks to the suggested solution. The trial also showed that the technology might help a blind individual navigate crosswalks and sidewalks with confidence.

Keywords: wearable device; visually impaired people; deep learning; semantic segmentation; depth map; obstacle avoidance

1. INTRODUCTION

The number of persons with visual impairment is expected to rise from 38.5 million in 2020 to more than 115 million by 2050, according to academic research [1]. Therefore, in the future, more focus from society and the government will be required. When going outside, those who are blind or have low vision require special equipment. The most well-known aids for the visually impaired right now are white canes and guide dogs [2]. White canes are convenient and inexpensive, but they lack the ability to offer visual information such as the position, kind, and proximity of obstacles. Outdoor navigation relies heavily on visual cues for both environment perception and safe movement [3]. However, guide dogs only have an 8- to 12-year lifespan [4], and the expense of breeding and training a guide dog is quite costly. Many experts in the field have worked to provide a wide range of aids for the visually impaired [5,6,7]. Assistive devices designed to help the visually impaired go about should have fast and accurate environmental recognition capabilities.

The group at [5] created a wearable gadget that emits distinct tones to alert the sight impaired to the presence of impediments in their path. It also utilized the frequency and volume of the signal to show

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the position of the obstructions. The authors of article [6] implemented the traversable direction visual improvement feature into wearable glasses using augmented reality technology to aid the visually impaired in securely navigating their environments. They also created three-voice cues to help the totally blind find their way around safely. It was suggested that the visually handicapped utilize a wearable navigation system [7] equipped with an RGB-D camera, a gyroscope, and a smartphone to help them avoid obstacles as they move through both indoor and outdoor settings.

Outdoor navigation for the visually impaired places a premium on the ability to avoid obstacles, cross streets safely, and follow predetermined paths. To this end, several helpful frameworks have been created that make use of mobile devices, sensors, and computer vision. The writers of [8] examined a number of comparable studies, weighing the benefits and drawbacks of each method. The authors of the research [9] employed RGBD camera pictures to train a semantic segmentation network and a classifier, allowing the visually handicapped to understand their surroundings while traveling on roads. However, the user is left in the dark if the option in front of them leads nowhere. Smart glasses and a laptop equipped with a real-time semantic segmentation network were utilized by Yang et al. [10] to guide the user. Using a set of smart glasses and a portable processor, the system presented in [11] may identify external landmarks such as guide bricks and crosswalks for those with vision impairments. In order to aid the visually handicapped in using the crossing safely, the authors of paper [12] built a segmentation network to locate crossroads and used a color space image processing approach to identify traffic signals. In order to assist the visually challenged avoid flying objects, the authors of article [13] employed a smartphone. Glasses with infrared (IR) transceiver sensors and a white cane with accelerometer and gyroscope sensors [14] help the vision handicapped navigate their environment and recognize when they have taken a tumble. The authors of article [15] suggest a sensor-based wearable device to aid the mobility of the visually handicapped. The paper [16] proposes a real-time object detection system that uses picture depth information and fuzzy logic to achieve high accuracy in obstacle avoidance. In [17], the authors use a smartphone's camera and inertial measurement unit (IMU) to create a navigation system that can help the vision handicapped both indoors and outside. Safe indoor walking routes were identified by Aladrén et al. [18] using a combination of floor-segmentation and road-segmentation. In order to help the visually handicapped navigate the outdoors without stumbling over obstacles, the authors of paper [19] created a navigation assistant based on convolutional neural networks (CNNs). However, it does not direct the user to utilize the sidewalk or crosswalks, which might be dangerous for someone who is blind or has low vision. In the study [20], a visual localizer was utilized to provide strong visual localization to aid the navigation of the visually handicapped. The visual localizer was made of a ConvNet descriptor and a global optimizer. [21] presented a wearable device using a CNN-based object identification model to identify crosswalks, which might be used to help the vision handicapped safely cross the street. Moreover, it gets the traffic situation using iAPS (intelligent, accessible pedestrian signal) methods.

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Creating a better walking aid for the visually handicapped is a subject of discussion in modern culture. This article describes a wearable assistive technology that may help the visually impaired navigate streets and crosswalks with more confidence and independence.

CNN: CNN is a popular tool for this, since it is an important subfield of deep learning [56]. Unlike traditional neural networks, CNNs include a feature-learning stage made up of convolutional and pooling layers. To alleviate the computational burden of training a conventional fully connected neural network, each neuron in the convolutional layer is not linked to all the neurons in the next layer. Fig. 1.

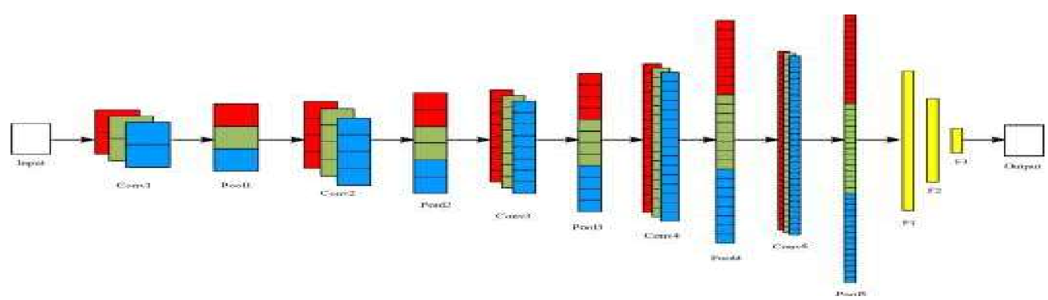

Fig. 1. The structure of a CNN.

2. RELATED WORK

A. Object Recognition Using CNN

One use of CNN-based models is in the field of object classification. LeNet [4] pioneered the use of a CNN-like framework for character recognition, inspiring subsequent work in the field. The ImageNet Large Scale Visual Recognition Challenge (ILSVRC) has been held annually since 2010 to see which classification algorithm can achieve the best degree of accuracy. Significant advancements with a deep CNN were shown by AlexNet [5] in 2012, when it achieved an error rate of 16% (down from about 25% as reported in 2011). After then, many started to see CNN as a real possibility for image classification. GoogLeNet [6] and VGGNet [7] were the 2014 ILSVRC's first and second place finishers, respectively. Despite GoogLeNet's more involved design, VGGNet achieved similar results. We have created an algorithm that uses convolutional neural networks to identify drugs in photographs.

Constraint-based CNN designs have the disadvantage of being difficult to train if insufficient data is available. For instance, VGGNet requires not just a large dataset but also a significant amount of time to configure its 138 million parameters. Similar limitations in the bioinformatics industry [8] were solved by using transfer learning [9]. Research into the classification of images using the method has also shown encouraging results. All parameters were taken from previously optimized work, and only freshly trained layers were utilized to tackle the problems of interest. ImageNet [10] provided a large enough dataset to train the feature extraction layers, allowing following studies to make use of the already taught models. Since drug identification is fundamentally a classification problem, we used transfer learning even though we were working with a small dataset.

B. Applications that Help the Blind

The advent and broad use of smartphones have resulted in the availability of a new resource to aid the visually impaired. Kramer et al. [11] developed a mobile app that uses facial recognition technology to aid police investigations. However, an active wifi connection to the facial recognition server was needed of the user. Similar to other technologies, ours was based on a recognition model, but unlike others, it was designed as a mobile app that could function offline as well. Rodrigues et al. [12] studied the smartphone habits of the visually impaired for 8 weeks. In this research, we questioned people who had used TalkBack (Android's screen reading accessibility features) and found that they felt the offered documentation wasn't enough to get them started. This is why we made available to the public our TTS service. However, our respondents favored the default accessibility feature of TalkBack (Section VI) because of its familiarity and dependability. ThirdEye [3] provided audio feedback in the vital areas of object recognition and optical character recognition. Commonplace things and the packaging of well-known medications like ibuprofen were no match for it. Be My Eyes [13] is an application that provides an alternate approach to object identification. A matching algorithm is used to set up video conversations between the visually impaired and the sighted. These people help the visually impaired with more difficult duties, such as preventing the spoilage of perishable food. Based on the interviews presented in Section III, it seems that both applications are rather well-liked by smartphone owners. While the latter demands the sharing of sensitive information about voluntary participants, the former was unable to effectively identify Korean domestic drugs. Seven domestically sold medications were categorized by Song et al. [14], although their system was not designed with the visually impaired in mind. Color, shape, and even the text on a pill's label were all utilised. The blind population in Korea is working to achieve more autonomy by learning to administer their own medicine.

3. RESEARCH METHODOLOGY

The Main Method

In this research, we develop and deploy a technology to help the visually impaired navigate pedestrian walkways and crossings without risk of injury. Specifically, this aide system alerts the visually impaired to the presence of the sidewalk, crosswalk, and impediments in their path, and then directs the user in a safe and appropriate way.

The Hardware System Configuration

The whole assistive system may be worn on one's person, and it consists of a binocular camera called ZED 2 and a gadget called Jetson AGX Xavier, which was released by Nvidia [22]. The AGX also has a voice prompt manager. In this setup, a sound card is linked to the AGX and the headphones to provide audible cues. There are 8 NVIDIA Carmel CPU Cores (compatible with ARMv8.2) and a GPU based on the NVIDIA Volta architecture with 512 CUDA cores included within the AGX's Tegra System on Chip (Xavier SoC). The AI computing performance is improved by the inclusion of a Tensor Core, an NVIDIA deep learning accelerator, a VLIW (Very long instruction word) video processor, and an image signal processor (ISP). The ZED 2 is a wide-angle stereoscopic camera ideal for monitoring moving targets like cars and people. The large 120-degree field of vision allows for superior depth sensing. People who are vision handicapped benefit greatly from these features. The goal here is to include object identification with depth-of-field detection (up to 20 m). Figure 1 depicts the whole of the assistive system, which is powered by a lithium battery with a 5200 mAh capacity (Figure 1a). With a fully charged battery (16.8V), the system can run for around 2.5 hours. The user's backboard houses the battery and AGX. As shown in Figure 1b, the ZED 2 is attached to the hat's brim. In addition, the sound card is linked to the headset, so the user may hear the voice instructions.

The System's Internal Software Architecture

Figure 2 depicts the system's software architecture; two deep learning models, Fast-SCNN and YOLOv5s, are responsible for the AGX's environment identification. Using the depth map generated by ZED 2, the output of FAST-SCNN can determine where the user may safely go and point them in the right direction. The YOLOv5s equipped with a depth map can see what's in the user's path and determine how far away it is. Additionally, the voice prompt manager creates audio guidance for the visually impaired client on impediments and walkability.

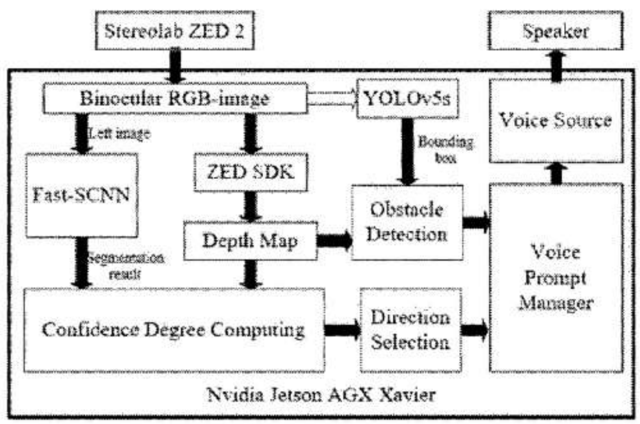

Figure 2. *The software structure of the assistive system.*

Vision-impaired people's essential job duties

In this section, we will present the main configurations of the system in detail and explain how the assistive system helps visually impaired people walk outdoors. Since the most common areas for visually impaired people walking are sidewalks or crosswalks. Recognition of sidewalks and crosswalks should be done first. Second, we should provide the user with the front environment information, either a completely open area or an area with objects. The third task is to select the correct direction for visually impaired people walking forward on the sidewalk or crosswalk. At last, we recognize the types of obstacles to visually impaired people such that the user can know what obstacle is in front of them. Therefore, the following subsections will describe the above three tasks respectively in a more detailed way.

Tasks That Can't Be Ignored for the Blind

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Here, we'll describe the system's primary configurations in depth and show how it may be used to aid the visually handicapped in outdoor walking. Considering that persons who are blind or have low vision often walk on sidewalks or crosswalks. Priority should be given to identifying crosswalks and sidewalks. Second, we need to tell the user whether or not the environment in front of them is empty or filled with obstacles. Third, those with vision impairments who are moving ahead on a sidewalk or crossing must choose the proper direction. We've now reached a point where the visually impaired user knows exactly what kind of barrier is in front of them. Therefore, the next parts will elaborate on the aforementioned three activities separately.

4. RESULTS AND OBSERVATION

Learning FAST-SCNN from Environmental Features

Our goal in developing this assistive technology was to ensure that the visually impaired user could safely navigate sidewalks and crosswalks. An efficient computation on embedded devices with little memory may be had with the help of the Fast Segmentation Convolutional Neural Network (Fast-SCNN) [23], a real-time semantic segmentation model on high-resolution picture data. Furthermore, compared to other popular segmentation networks, Fast-SCNN uses less parameters [24]. As a result, we used Fast-SCNN as the segmentation model to identify features of the natural world such concrete walkways, stone pillars, wooden steps, and asphalt streets. Here, we assume that persons with vision impairments can only navigate their way about via sidewalks and crosswalks.

The Fast-SCNN was trained using an extensive collection of street-level pictures taken by people near the test area. Our dataset included outdoor areas that pedestrians use the most, such as sidewalks, crosswalks, stairs, and roadways. Training data (link: https://github.com/kev72806/TW-NCU-ICIP-Lab-dataset (accessed on 24 October 2021)) was specifically gathered during daylight hours, on sunny days, in all four seasons. There are a total of 22,798 pictures in the training data set, consisting of 3673 unique captures and various forms of augmentation. Since the photos were continually captured by ZED 2 video, we randomly selected 10% of the total images as the validation set and removed duplicates. In addition, we used MATLAB Image Labeler to assign labels to individual pixels in our dataset. Table 1 displays the complete data distribution. To complete the data enhancement, try using the following strategies: First, randomly spin it counterclockwise or clockwise within 5 degrees, trim 80% of the original size from the middle, then increase it back to its original size; second, adjust the image's brightness by a fixed amount; and third, flip it horizontally. Put that training data to use to educate a Fast-SCNN network. The settings and/or data used to train the network are listed in Table 2.

Table 1. The data distribution.

Table 2. The parameters used in network training.

International Journal of Multidisciplinary Engineering in Current Research - IJMEC
Volume 8, Issue 9, September-2023, http://ijmec.com/, ISSN: 2456-4265

In order to help the user find the sidewalks, crosswalks, stairs, and asphalt roads in their immediate vicinity, the Fast-SCNN generates a segmentation result for the picture in front of them after training. In Figure 3, the left and right panels show the original capture and the output of the semantic segmentation, respectively. Crosswalks are green, blue, grey, and red, while sidewalks, asphalt roadways, and staircases are all represented by different hues. The results of Fast-SCNN in terms of pixel precision and Intersection over Union (IoU) are shown in Table 3.

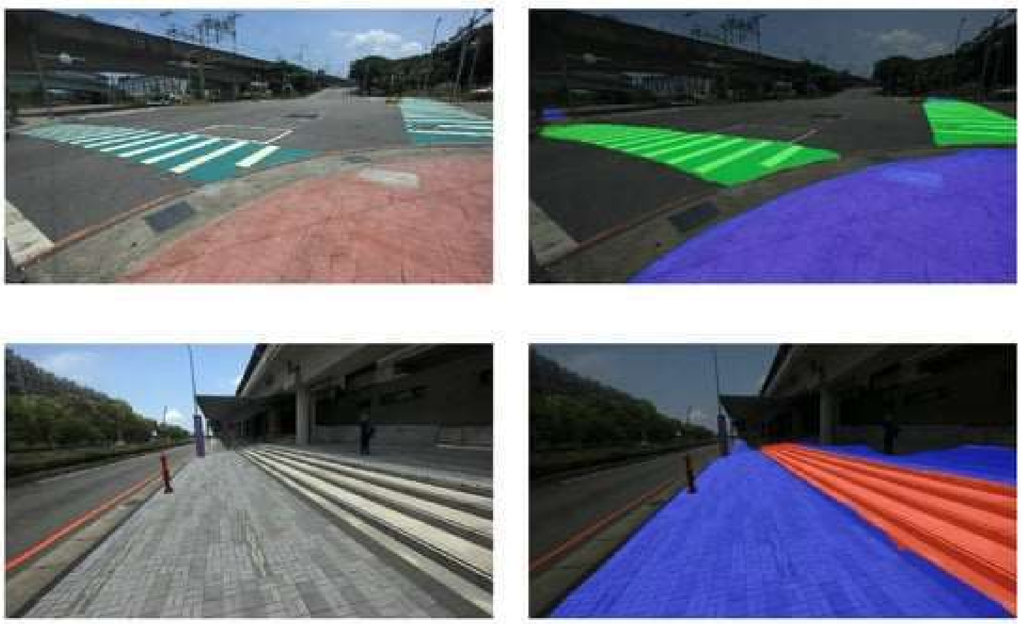

Figure 3. *Street view image from ZED 2 and the result of Fast–SCNN.*

Table 3. The performance of FAST-SCNN.

The Depth Map in Conjunction with the Openness Values

The FAST-SCNN can identify the aforementioned six street scenes in front of visually challenged people, but it lacks the ability to provide a distance estimate for the scene. Because of this shortcoming, ZED 2 supplies the depth map for the subsequent picture. ZED 2's color photo should be placed on the far left of Figure 4. The ZED SDK produced depth map is the one in the center. For instance, in Figure 4, (a) is the original color picture and

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(b) is the depth map that corresponds to (a). Let's assume that the depth map pixel's coordinates (i, j) have a corresponding value, Md(i, j), defined as

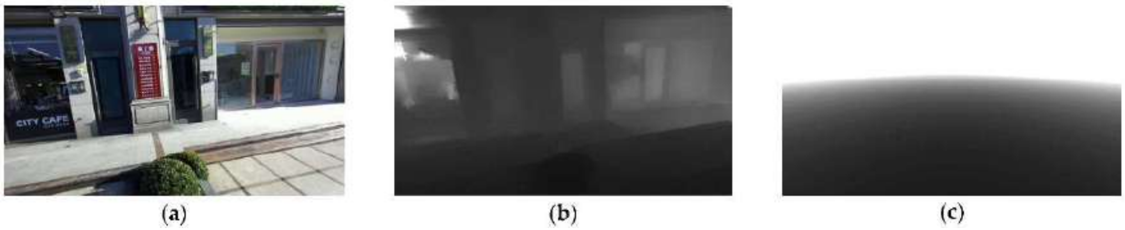

Figure 4. *(**a**) The original image; (**b**) the real depth map corresponding to the image in (**a**); (**c**) the depth map of a completely open area.*

Decisions Regarding Which Way to Walk

Semantic segmentation in this investigation assigns the colors blue and green to the pedestrian walkway and the crossing. Assume the user's height to be HH (m) and place the ZED 2 in the user's cap. When looking straight ahead, the camera's field of vision spans a distance of around 3.52 x 3.52 x 3.52 meters at its narrowest point. From left to right, we create seven equal sections and label them 0 through 6 (see Figure 5). When the HH is 1.7 m, for instance, each section is around 3.52H/7=0.863.52H/7=0.86 m broad, which is plenty for a human to pass through unimpeded. We want to choose the best division out of these seven to recommend to the visually impaired user the direction they should go in.

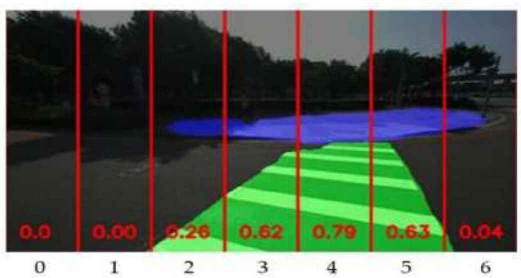

Figure 5. Seven divisions with $Conf_S$.

Approach as a Walking Guide

We provide a walking guide method for the visually impaired user when the confidences for seven divisions have been established.

First, if the middle division's Conf is more than 0.5, the middle division will be selected and the audio prompt will advise the listener to "go straight." If Conf is not selected across all departments, go to Case 2.

Case 2: Locate the section with the greatest Conf (more than 0.2) across all sections; then direct the user to that section using verbal cues like "slightly right/left," "right," or "go straight."

In Case 3, if all Conf values are less than 0.2, the user has reached a dead end and must backtrack. And that happens whether the consumer is looking up or down. As a follow-up, the voice prompt says, "dead."

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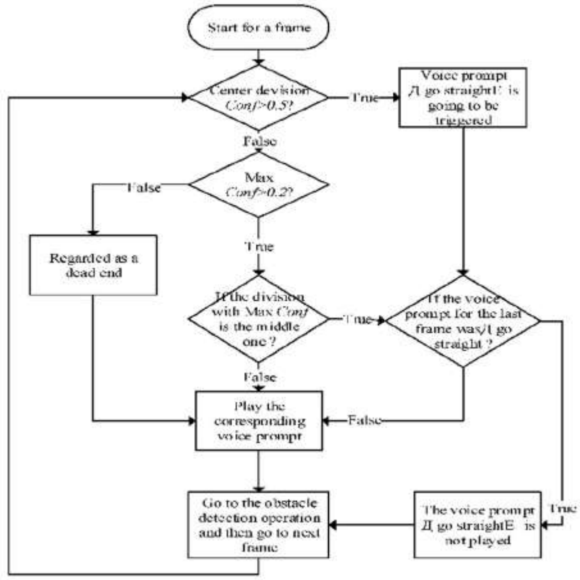

Figure 8. *The flowchart of the walking guide strategy.*

5. Conclusions

In order to prevent the visually handicapped from colliding with objects when walking on the sidewalk or crosswalk, this research proposes a wearable assistive device. Using the depth map generated by the ZED 2, we were able to determine how far away an item was from the user by training a semantic segmentation model to detect the user's surroundings. We have created a walking guide method for the blind by combining the aforementioned two types of ambient data. In addition, roadblocks were specifically included into the object detecting model YOLOv5s. The experimental results demonstrate that a visually impaired user may navigate the sidewalk and crosswalk without colliding with any obstacles while using the suggested assistive technology. However, we must concede that the user may not have time to dodge an item that suddenly arrives in the camera's blind area within 0.2–1 m in front of them. The white cane is still useful in this context for the sight handicapped. For this reason, we advise the visually impaired individual to continue using the white cane with the assistive device. Furthermore, the research on blind persons using a traffic signal junction is ongoing. Northern Taiwan's junction traffic light timing and status is available on the "Invignal" traffic light platform. Our subsequent experiment will make advantage of this infrastructure. If subsequent experiment results are more consistent, we will share our findings. In addition, we want to conduct more tests with other people who are visually impaired in order to ensure the efficacy of our suggested method. We have repeated several studies using the few available testers, and the results are almost always the same.

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