Path Hole Detection to Assist the Visually Impaired People in Navigation

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Abstract—The number of visually impaired people is increasing with the rapid growth of population. The visually impaired people face much difficulties in their daily living owing to losing their vision. Path hole is a major hindrance to their walking. So path hole detection has become a prominent issue to aid the visually impaired people. We proposed a solution by detecting path hole on the road surfaces using Convolution Neural Network. The proposed system is able to classify the road surfaces with path hole and non-path hole. We have used two benchmarked dataset named as KITTI ROAD and Pothole detection. We have trained Convolution Neural Network with training-testing partition. The performance of the system is measured in terms of accuracy, precision, recall and error rate. The overall accuracy and error obtained by the system are 97.12% and 0.065 respectively in testing phase for 20 iterations. Additionally, precision and recall obtained by the system are 96.68% and 95.77% in testing phase.

Keywords- Path Hole; Convolution Neural Network; Visually Impaired People; Road Surface; Walking Assistant.

I. INTRODUCTION

A recent statistics from WHO shows that about 285 million people in the world are approximated to be visually impaired. Among them 39 are blind and 246 million have a slight vision [1]. Generally, the people over 60 years old have more risks of blindness and the number is rising by 2000 thousand per decade. An estimation shows that the number of blinds may be doubled in 2020 [2].

Blindness is the condition of lacking discernment because of physiological or neurological components. It is an interruption to some day-to-day events and there is a lack of sufficient assisting tools [3]. It is a standout amongst the most extreme sorts of handicaps a man must persevere through and, in spite of various progressions in innovation, it remains a significant issue till now [4].

The development of walking assistants has become a challenging issue and the necessity of the assistance devices is still now endless. However, there are many navigation tools and frameworks accessible for the blinds. The most significant devices are the dog guides and white cane. Though they are very famous, they are limited to speediness, coverage, and capacity which are normally accessible to persons having eyes for navigation [5]. Walking assistants [6] were acquainted with taking care of the day to day issues associated with navigation and location aids since 1960s. The assistants aid the visually impaired people by detecting and locating the obstacles around them using the sensors that take the sense from the exterior situation [6].

Though a number of researches have been demonstrated, almost all of the researches are not able to classify the road surfaces with path hole and non-path hole. To aid the visually impaired people, previously we have proposed few approaches as shown in [7], [8]. However, these approaches are able to detect the obstacles in front of the visually impaired people. These tools are sensor based and are able to detect the obstacles and generate an alarm signal to notify the users but can't detect any holes on the road surface. There is a suggestion from orientation and mobility experts that there is an absence of tools to distinguish path hole and uneven asphalts which restrains safe mobility. From this motive, we propose a strategy to detect the path hole from the input images. Deep Learning approach has been used to classify the road surfaces with path hole or not.

The remaining part of the paper is organized as follows: The related work that covers the recent developments in this area is described in Section II. The proposed methodology including the dataset collection and convolution neural network is illustrated briefly in Section III. Section IV outlines the experimental outcomes of the proposed system. Section V concludes the paper.

II. RELATED WORK

Several assistants are developed to guide the visually impaired people for easy walking. Many organizations have been working for a long time to make cost-effective and well-organized tools for them. The work associated with this field is outlined briefly as follows.

Rao et al. [9] proposed a computer vision based pothole detection system for the visually impaired people that is helpful in their safe mobility. The scheme records the pattern and extract the features from the pattern and give the proper way of waking by analyzing the features. The data was collected by a camera with a laser. The system detects the pothole with 90% accuracy. The system worked in the real-time environment. The major limitation of the system is that it is only appropriate for the dark environment as the laser patterns are visible only in dark.

Madli et al. [10] presented an automatic pothole and humps detection system for autonomous vehicles. The presented system used a global positioning system to take the geographical position coordinates of the potholes and humps which includes the depth and height of the potholes and humps. The data that are sensed are stored in a cloud database. For a particular location, the data of the road remain stored in a database. When tracking on the road, an alert signal with the depth and height of the potholes and humps are sent to the driver using an android application. The ultrasonic sensors are used to collect data but the sensors readings are changed with the variation of temperature and humidity which misguide the vehicles.

Harikrishnan et al. [11] introduced a road monitoring system that is able to detect the pothole and humps on the road surface and predict their harshness from vibration signal generated by vehicles. The smartphone accelerometer is used to capture vehicle vibration along z-axis and the pothole or humps are detected using x-z ratio filtering. The system also estimated the depth and height of the potholes and humps respectively. The system is able to detect the pothole and hump but can't detect Expansion joints, Manhole and Pipeline holes etc. The authors in [12] evaluated the performance of pothole detection system with an image classification modality using deep convolutional neural networks. The system is evaluated in terms of grayscale and color image. The system used 3028 images for training and 159 images for testing with 5000 iterations. The experimental results show that the classification accuracy obtained by the system is 96.5~97.5%. The system used some deep learning toolbox which is not best practice to evaluate the performance of a system.

Zhou et al. [13] developed a smart system named as "Smart Eye" to help the visually impaired people by informing them about the surroundings. The system has two module such as the embedded wearable sensor and smartphone module. The wearable sensor module consists of power (9-V dc battery), CPU (32-b mbed NXP LPC1768), sensor (Ultrasonic Sensor, Motion Sensor) and communication (Bluetooth or Wi-Fi chip) parts. An android application is developed to provide the distance warning to the user that is returned by ultrasonic sensor. The communication between embedded module and smartphone is done by Bluetooth or Wifi. The developed application is vigorous and detects the obstacles about 10 feet away. O'Brien et al. [14] discussed a cost-effective electronic tool integrated with a conventional cane that provides an alarming signal by detecting the obstacles. A custom-built printed circuit board integrated with a microcontroller drove the sensor and motor. The weight is approximately 110g including battery. The system calculated the distance when notifying the obstacles. If the calculated distance is between 0.2-0.6m, and an alarm signal is generated and if the distance is within 0.6-1m, then another signal is generated. If there are no obstacles within 0.2-1m, the system searched for another obstacle. So, we can conclude that the system can detect the obstacles within 1m range.

Kaushalya et al. [15] developed walking assistants named as "AKSHI" to aid the visually impaired people using Raspberry Pi 2, Ultrasonic sensor, GSM module, RFID reader, and tags. The system is able to detect the obstacles as well as locate them with lesser cost. The RFID reader is attached with the bottom part of the stick that can detect the obstacles though RFID tag. The Ultrasonic sensor is placed below the circuit box on the track of 45^0 angles. Another box including Raspberry Pi, GSM, and GPS Modules are attached with the stick. A mobile application is also developed to keep the track of the user location using GSM, GPS Modules. The system is not compatible with offline connection. Bhatlawande et al. [16] proposed an electronic mobility cane for the visually impaired people for way-finding as well as obstacle detection. The system develops a logical map of the surroundings and keeps them on priority basis. It provides the priority information to the users using feedback signals like voice, vibration or audio. It is also able to detect the staircase and floor status. The system comprised of embedded system with ultrasonic sensors, liquid, and metal detection sensor, wireless transceivers, battery and microcontroller circuits. The system is able to collect and categorize the information of surroundings. The system is tested with few number of real-world trials.

Bai et al. [17] developed a smart guiding tool look like as eyeglass to aid the visually impaired people to move safely. The system comprises of pair of display glass and some developed sensors which are cost effective that was tested by several people. The system worked in indoor environment only. The developed system contains a depth camera to gather information from surroundings, ultrasonic sensor and microprogrammed control unit used for obstacle distance measuring, a CPU for image processing, and sound analysis etc. Audio instructions are provided as feedback with the presence of obstacles. The system is tested in home, office and supermarket environment. The proposed glass is more efficient and very supportive for the eye insight people in indoor environment. Vera et al. [18] proposed a framework named as "Blind Guide" for the visually impaired people to navigate them in interior and exterior environment using wireless sensor networks. The system combined with various wireless sensors which can be utilized in various portions of the body. The sensor is able to detect the obstacle as well as give an audio signal as a feedback. The hardware component used in the scheme are the peripheral sensor, ultrasonic sensor, Wi-Fi microcontroller, a central device including camera module, raspberry pi, and a speaker. An audio signal is sent to the central device when the object is detected. After that, the central device capture an image of the object with the help of camera module and the image is sent to the cloud image recognition service. The system is able to identify chairs, tables, doors, walls and ordinary objects in the interior environment and avoid the common obstacles in the exterior environment.

(a) (b)

Fig. 1 Sample images: (a) Road surface with non-path hole (b) Road surface with path hole.

III. THE PROPOSED METHODOLOGY

The proposed methodology is followed by some steps involving the dataset collection, convolution neural network and performance evaluation. Each step is described briefly as follows.

A. Dataset Collection and Description

The road surface dataset with non-path hole is retrieved from KITTI ROAD dataset [19] that contains 289 images. The road surface dataset with path hole is retrieved from pothole detection dataset [20] that contains 90 images. The total images in the dataset 379. We have used (70-30)% training-testing partition. The training set consists of 260 images and the testing set consists of 119 images. Among these images, some images are shown in Fig. 1 for easy understanding.

B. Convolution Neural Network

Convolutional Neural Networks (ConvNets or CNN) [21] are a category of Neural Networks that have been demonstrated very real in the fields such as image recognition and classification. Because of its classifying visual patterns such as pixel images with a very few pre-processing, it has added a new dimension to image classification tasks [22]. A CNN entails of some layers. The layers of CNN are Convolution layer, Pooling layer, Activation function and Fully connected layer. Each of the layers of CNN are described below.

(i) *Convolution Layer:* The basic role of Convolution in case of a ConvNet is to excerpt features from the raw/input images. Convolution preserves the spatial connection between pixels by learning input image features with trivial squares of input data. Convolution is a numerical term applying a function on the output of other functions recurrently. Convolution will generate a direct change of the input data corresponding to the spatial information from the filter.The weights on that layer whether determine the convolution kernel is utilized or not. So the convolution kernel may be trained in view of input on CNN.

(ii) *Pooling Layer:* Pooling layer is also known as sampling layer. Pooling layer [23] diminishes the spatial size and number of parameters in the system and quickens computing and controls the event of overfitting. Spatial blocks move along the feature pattern which is the main working principle of pooling layer. The average pooling, max pooling, and Lp pooling are the main categories of pooling layer. Among them, max pooling is the most popular.

(iii) *Activation Function:* Activation functions [24] are a vital portion of CNN whose mission is to make the neural network nonlinear. The activation function is also known as transfer function which is a non-linear function mainly used to solve nontrivial problems. The activation function receipts the input value from network for the mathematical task. The activation function calculates the feature output map in the CNN architecture. In some cases, it produce a feature pattern after the convolution or pooling calculation procedure. The sigmoid function, tanh, Rectified Linear Unit (ReLU), Leaky ReLU (LReLU) and Parametric ReLU are the activation functions that are widely used in CNN architecture. Among them, ReLU or Rectified Linear Unit is the most prominent.

(iv) *Fully Connected Layer:* The Fully Connected layer is a traditional Multi-Layer Perceptron that uses a softmax or sigmoid activation function in the output layer.The term “Fully Connected” implies that every neuron in the previous layer is connected to every neuron on the next layer. The output from the convolutional and pooling layers represent high-level features of the input image. The purpose of the Fully Connected layer is to use these features for classifying the input image into various classes based on the training dataset.

This network that we have developed consists of two convolutional layers and two subsampling layers each following only one convolutional layer. For both convolutional layers, the kernel size remains fixed and is 3x3 where in both subsampling layers, the size of the pooling area is 2×2. Following this is a dense layer, containing a linear representation of the terminal subsampled feature map’s units those are connected to the 2 neurons in the output layer for classifying images into 2 classes. Path hole are determined from a particular neuron in the output layer and non-path hole are determined from another neuron. When the path hole neuron value outputs 1, the other neuron value goes 0 and vice versa. The kernels, as well as the hidden-output weights, are updated while training process continues for a 20 and 30 number of epochs. The input images are in size of 32x32. We have used max pooling operation with the size 2x2 and ReLU as an activation function.

C. Performance Evaluation

To measure the performance of the path hole detection system, some measures are used. The measures are the Mean Square Error (MSE) and Accuracy. Actually, our target is to minimize the error rate and maximize the accuracy. The mathematical representation of the performance measure parameters is given below.

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FP+FN)} \quad (1)$$

$$\Pr ecision = \frac{TP}{TP+FP} \quad (2)$$

$$\text{Re}\,call = \frac{TP}{TP+FN} \quad (3)$$

where,

TP = *True Positive (Correctly Identified)*

TN = *True Negative (Incorrectly Identified)*

FP = *False Positive (Correctly Rejected)*

FN = *False Negative (Incorrectly Rejected)*

IV. EXPERIMENTAL RESULTS ANALYSIS

The experimental results that were obtained to measure the performance of the proposed system are described shortly as follows.

A. Experimental Setup

We have implemented the proposed work in Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz powered computer with 8GB of RAM for processing purpose. We have used Spyder which is an integrated development environment for python and builds the program using Keras.

B. Results Analysis

The experimental results show that the CNN generates a path hole detection system with high accuracy where the experiments are performed 20 and 30 times (epochs). In every epoch, we measured the mean square error, accuracy, precision and recall both for training and testing phases. The overall accuracy and error obtained by the system are 97.12% and 0.065 respectively (in testing phase). The accuracy 97.3% and error 0.062 are achieved in training phase. The error rate both in training and testing phases are represented in Fig. 2.

From Fig. 2, it can be shown that the error of the system is varied from 0.0020 to 0.5412 in training phase and the error of the system is varied 0.0087 and 0.52 in testing phase. The performance measure parameters are shown in Fig. 3 and Fig. 4 both in training and testing phases respectively. From Fig. 3 and Fig. 4, it can be observed that the accuracy of the system is varied from 0.7253 to 1.00 in training phase and the accuracy of the system is varied from 0.7501 to 1.00 in testing phase. The precision and the recall values are varied from 0.0172 to 1.00 and 0.0916 to 1.00 respectively in training phase. We have run the program several times to realize the effects of a number of epochs on the results. It has experimented that with the addition of several epochs, the error rate decreases near about 0 which is shown in Fig. 5 and the overall accuracy and recall of the system increases which has been illustrated in Fig. 6 and Fig. 7 in training and testing phases respectively.

From Fig. 6 and Fig. 7, it can be observed that the accuracy and recall both in training and testing phases increase with the addition of a number of epochs and the precision is decreased. The error rate both in training and testing phases decrease with the addition of a number of epochs. With the addition of epochs, the network is trained in a better way.

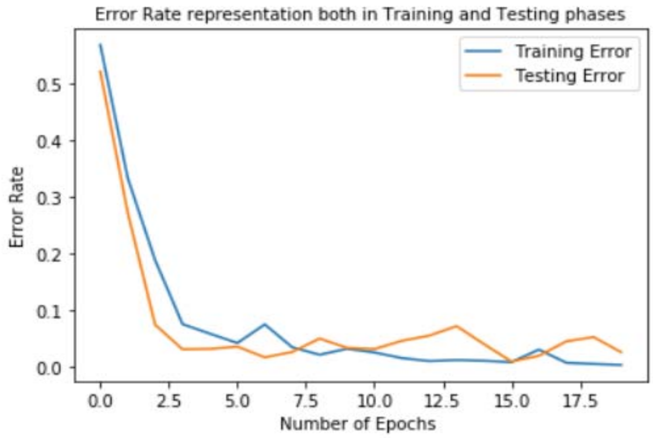

Fig. 2 The error rate both in training and testing phases for path hole detection system (20 epochs).

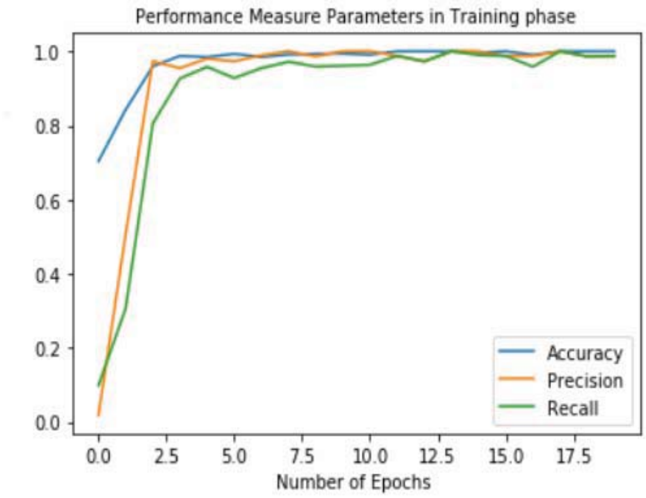

Fig. 3 The performance measure parameters for path hole detection system in training phases (20 epochs).

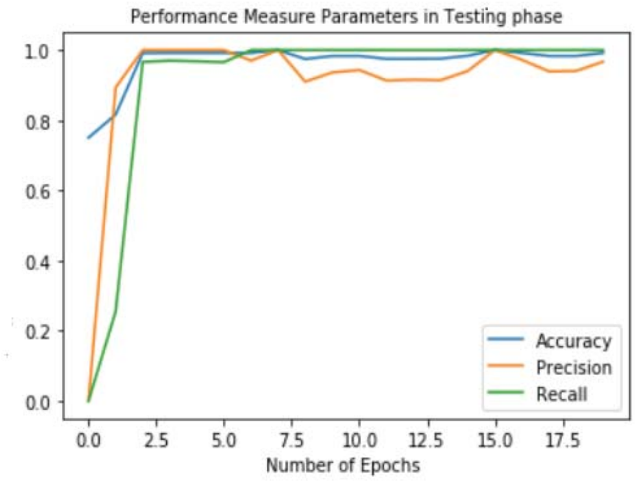

Fig. 4 The performance measure parameters for path hole detection system in testing phase (20 epochs).

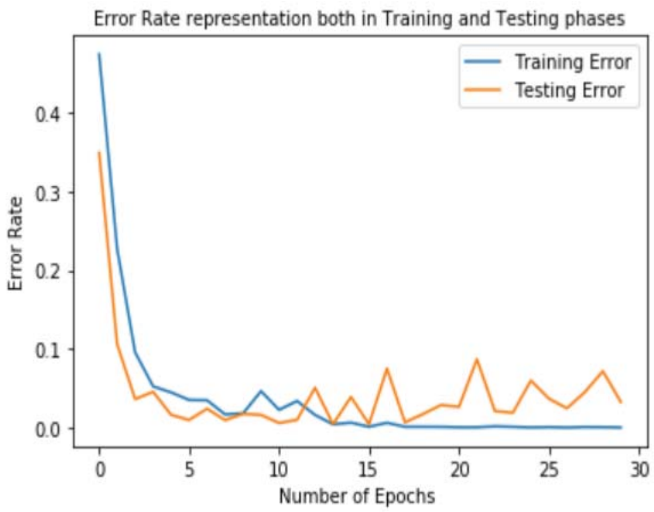

Fig. 5 The error rate both in training and testing phases for path hole detection system (30 epochs).

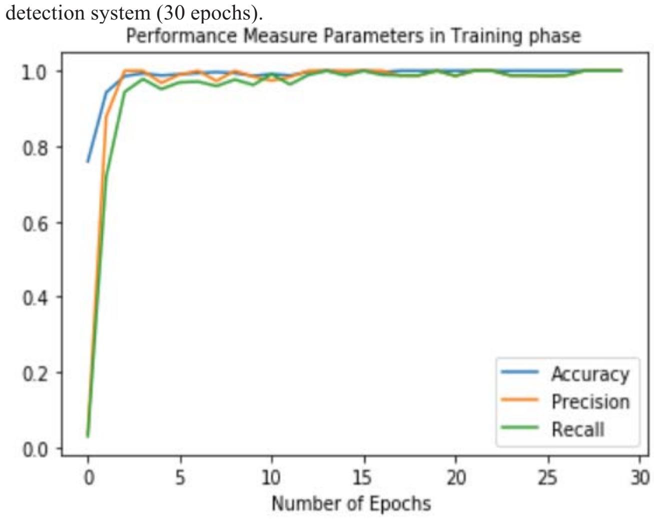

Fig. 6 The performance measure parameters for path hole detection system in training phases (30 epochs).

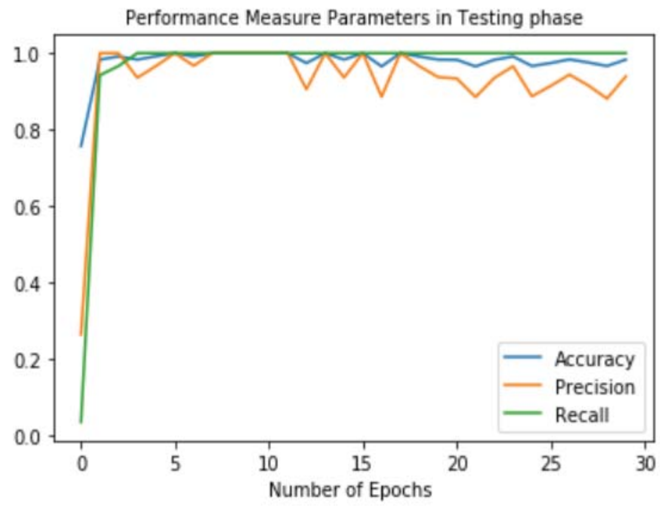

Fig. 7 The performance measure parameters for path hole detection system in training phases (30 epochs).

V. CONCLUSIONS

This paper presents a Convolution Neural Network based path hole detection system that can detect the path holes on the road surface. We have evaluated the performance of the path hole detection system on the two benchmarked datasets. The overall accuracy and error obtained by the system are 97.12% and 0.065 respectively (in testing phase) for 20 iterations. As the system contained a few numbers of images, the system performs better with less number of iterations. The system is very supportive for the visually impaired people to avoid a hole in the road surfaces while walking. In future, this work may be integrated with a single device like spectacle that can generate an alert signal with the presence of path holes.

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