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Original Research Paper

Computer Science

A REAL TIME STAIRCASE RECOGNITION FOR VISUALLY IMPAIRED USING CONVOLUTIONAL NEURAL NETWORKS AND A DEEP LEARNING APPROACH

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ABSTRACT There have been numerous attempts to help facilitate the independent movement and travel of the visually impaired. In simple words, different techniques have been employed to detect the obstacle in front by various methods like ultrasonic, IR, simulating the environment by taking photographs etc. Most of the systems that are practical are rather complex, expensive and with moderate accuracy. Therefore, the objective of this paper is to develop a model with decent accuracy to warn the visually impaired pedestrians about the presence of staircase in front of them. Convolutional neural networks are used, and this deep learning model is trained over a dataset of 524 images of different types of staircases.

KEYWORDS : Deep Learning, Convolutional Neural Networks, CNN, Staircase Detection, Machine Learning

INTRODUCTION

Blindness is the partial or complete loss of visual perception due to physiological or psychological factors. Blindness is considered to be among the sensory disabilities that have the greatest impact on everyday life. As we are aware that the estimated number of blind people increased (by 42.8%) from 34.4 million in 1990 to 49.1 million in 2020 yet global prevalence of blindness decreased between 1990 (0.85%; 95% UI:0.68%-1.1%) and 2019 (0.60%; 95% UI:0.48%-0.75%). Majority of these people are helpless, and they have to go through a number of problems in their daily life. With no significant help, they cannot achieve their major tasks and comply to their day-to-day routine.

In this paper, we are proposing a model that will help the visually impaired people to recognize the presence of staircase, that is, one of the most important areas a person encounters in day-to-day life. Many a times, the people with physiologically normal eyesight also suffer with accidents in correlation to staircases. So, to overcome this problem faced by visually impaired people, we have built a model that will help them recognize a staircase.

An effective indoor staircase detection algorithm based on an RGB-D camera was found to be an efficient technique [1] Different kinds of techniques can be seen to have been used for the purpose of detection of the obstacle that is right in front of the person who is visually impaired by various different kinds of methods and to enlist a few, IR is one important, ultrasonic is another and simulation of the environment by the means of taking photographs etc. Many of the systems that we can consider as practical are perhaps very expensive and can be said as complex. Therefore, the theme of this paper is to develop a cost-effective device that warns a blind pedestrian of obstacles in front of him [2]. Something like a monitoring system that is just about in the process of being enhanced is found to be making use of motion detection technology significantly modified different algorithms, implemented in Matlab and perhaps C sharp [3]. Implementation and analysis which is theoretical in format of the autonomous detection of an staircase and an algorithm on stair climbing on a mobile robot that is novel are presented here [4]. Here, on the basis of edge detection of apparently the stairs, a different kind of method for the use of properties of statistical form of projection histogram for the purpose of identification of the stairs is proposed. A set of methods to take the stairway area from the image is proposed, and this method is combined with the projection histogram to further identify the stairway [5]. In this paper, smartphone is used to take image and detect stairs, using navigation method. They also use Fourier transform [6]. In this paper, we deal with perception task of wearable navigation assistant. Modelling algorithm and depth sensing capacities of RGB-D cameras have been used [7]. In this paper, moving steps are detected using Microsoft Kinect. Also, the depth information of front faced image is captured with this software [8]. In this paper, they have proposed algorithm based on range data. They introduce parameter which describes local surface orientations. Secondly a filter is used to detect relevant edge [9]. The method in this is based on detection and clustering of patches that have surface normal vector oriented towards upward direction [10]. The field in which obstacle is detected is apparently a broad field and a huge number of systems for the purpose of obstacle detection have been brought into development in the past few years in this domain. We have found that, main character identification has been tried here regarding an obstacle detection system from the scene. Thus, it is clear that they have made an effort to classify the sensor types which are considered as main in regards with this field in passive (cameras - visible and infrared spectrum) and active (laser-scanner, radar, sonar) sensors and have been able to make a survey in the same domain [11].

The process of identification of the presence of a staircase is heavily complex for the visually impaired people. Hence, a system which is intelligent is highly required for the purpose of helping them. Here, the investigation is done with use of only a single sensor which is an ultrasonic one for the detection and recognition of staircases and floors in the electronic white cane. Object recognition system's performance is found to be depending on two thing of which one is object representation and apparently another is algorithms for classification. Initially, the unique representation of a spectrogram helps explain the variance of the spectral density of nothing different but ultrasonic signal. Then, representation of spectrum helps show the amplitudes which can be said as a function of frequency [12]. Here, the description of a system which is real time based for the purpose of human detection, motion analysis and tracking. This is a unique system which can be pronounced as an automated system for video surveillance for the purpose of detection and monitoring people in different environments which are indoor and outdoor. The tasks of tracking and detection are found to have been achieved by a number of steps: initially, an adaptive background and a robust model that happens to be able of dealing with changes in lightning, long term changes that can be found in the objects occlusions and scene is developed. This model is used in a way of apparently getting pixels of foreground by using the method of subtracting the background. Later on, cleaning

of noise and detection of object are applied, which is followed by human modelling to detect and to help in monitoring activity of humans in the scene like walking or running of a human [13]. Here, the staircase detection problem, in a context such that it can be used as an aid of navigation for the blind people is mentioned. There are certain requirements for the system that is discussed and they are viewpoint robustness, distance, scale, operation in real-time, rate which is high for detection and rate which is low for false alarm. Although, many false alarms are produced. We can observe that rate of false alarm is reduced drastically use of spatial context in the ground planes estimated form, and by enforcing consistency which is temporal are found to be presenting great quantitative results here [14]. A different strategy for the purpose of detection of descending-stair, approach, and apparently traversal with the use of inertial sensing and a apparently a camera which is monocular in nature is mounted on a tracked vehicle which is autonomous is explained clearly in this paper. At the very center of the algorithm, the main points are embedded such as different vision modules which can help in the exploitation of optical flow and texture energy are present. As we can find the robot navigating in a direction which is downstairs, it can apparently estimate its three degrees of freedom with the help of fusion of velocity which is rotational and its measurements with the help of a gyroscope which is of a tri-axial and is on the orbit with line observations of the camera's detected stair edges [15]. In this paper simple, efficient approach based on ultrasound sensing measures the distance from the user's head to the ground and detects changes that represent a step up or a step down [16]. In this paper, a stair detection algorithm that runs in real time on devices with low computational capabilities is presented. This method provides real-time performance on a mobile device [17]. An efficient algorithm uses image processing to detect the presence of stairs. They also use Fourier transform. Smartphone is used to take image and detect stairs, using navigation method [18]. In this paper, a framework which is new and unique is used for the purpose of detection and recognition of pedestrian crosswalks and stairs using a camera of the kind of RGBD is developed [19]. An algorithm which solves the detection of one of the most common features any person can come across during his daily life: the stairs is developed here [20]. Robots use two system, balanced system and computer vision system. For balanced system, we find region of interest (ROI), and find central point of ladder and we detect the edge of stairs by computer vision algorithm [21]. Here three frame difference method and one reference frame for comparison are considered. Firstly, they setup a threshold value for correct detection [22]. A navigation and wayfinding aid which is computer vision based can drastically help in improving the ability to be mobile of the visually impaired. Here, a unique framework which is new for the purpose of detecting and then recognizing the stairs, crosswalks of pedestrians, and traffic signals on the basis of RGB-D images was brought into use [26]. A real-time wearable, stereo-vision based, navigation system for the visually impaired is developed. It is found to be consisting a stereo camera which is head-mounted and a four tactile feedback effectors vest interface. The system uses a stereo camera as a data acquisition device and implements a Realtime SLAM, an obstacle avoidance, and a path planning algorithm [27].

Video processing and that too real time based and apparently analysis are gaining recognition in different systems that are technical and are able to provide good applications in models for the blind's assistance [28]. A type of implementation which is certainly efficient of a system which is used in real time for the purpose of staircase detection is proposed and is brought into action in way such that the implementation is carried out on a smartphone for the purpose of helping the world to get aware about the visually impaired people. The proposed algorithm uses an efficient image processing to detect the presence of stairs and its location within the image [29].

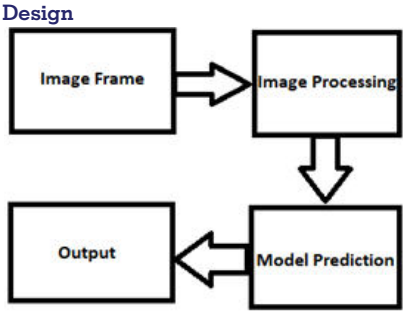
Some used hybrid approach to perform different tasks concerning to the visually impaired. It involves use of both, the sensors and cameras with processing devices. There were various types of algorithms used to extract the stairs/escalator from images captured with the mainly RGB-D cameras in a hybrid approach. They used both sensors and CV techniques together to make the system more accurate and faster. We have used a deep learning based approach to recognize the staircase which gave better accuracy.

Table – 1 Researchers And Their Approaches Relevant To Our Research Area.

Authors	Approach
E. Mihankhah	Projection Histogram
X. Huang and Z. Tang	Fourier Transform
A. Prez-Yus	Microsoft Kinect

METHODOLOGY

A. System Design



B. Sample Creation and Image Acquisition

We have collected a dataset of 524 images of staircases in different surroundings such as, staircase in a garden, staircase inside a house, etc. We have collected our dataset from 3 different open-source dataset websites such as MIT Vision Datasets, Enorasi datasets and GitHub.

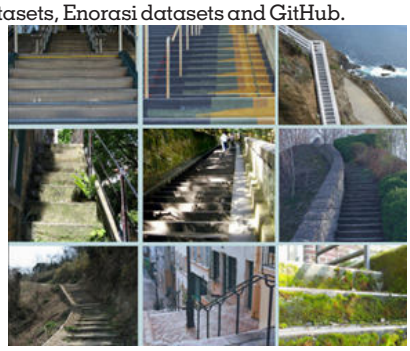


Figure a - Sample of dataset of Staircases.

We have also collected a dataset of walls inside a house as well as some walls in the outdoor surroundings which were 68, doors which were 268 and floors which were 32 for the purpose of training them as negatives to our model. When our model recognizes something as a staircase, it should also understand what a staircase is not.

Figure b - Sample of dataset of Negatives

C. Data Splitting

The entire dataset which was used in this model was split into 3 categories. One part was used for training the model, one part was used for validation and one part was used for testing. Out of the total 524 images, 20 random images were reserved and used for the purpose of testing. Out of the remaining 504 images, 80% were used for training purpose and the remaining 20% were used for validation. The use of the dataset of validation is to apparently give an estimate which is totally unbiased of the final tuned model's skill when the situation comes about making a comparison or of selection from the final end models.

D. Data Preprocessing

We have rescaled all the images in our dataset as rescaling and resizing a very critical step in computer vision. Principally, deep learning model architectures require our images to be of the same size. We use image normalization process that change the range of pixel intensity values. This process is done to normalize some images which have poor contrast due to glares. The motive here is to achieve consistency in dynamic range for a set of data. We have used a brightness range from 0.5 to 1.5 A random seed is used here to ensure that results are reproducible. In other words, using this parameter makes sure that anyone who re-runs our code will get the exact same outputs.

E. Model Architecture

We have used batch normalization to avoid overfitting in the architecture. Batch normalization is apparently a layer in which learning occurs more independently of the network's every layer. It is brought into use in our model for the purpose of normalizing the previous layer's output. Using batch normalization, learning becomes efficient and also it can be used as regularization to avoid overfitting of the model.

We have also used Adam Optimizer and Categorical Crossentropy. Adam is an algorithm of replacement optimization which is perhaps brought into picture for stochastic gradient descent and used for the purpose deep learning model's training. It is used to provide an optimization algorithm that can handle sparse gradients on noisy problems. Categorical crossentropy allows us to compute the loss value for multiclass classification while remaining flexible with respect to the actual target class.

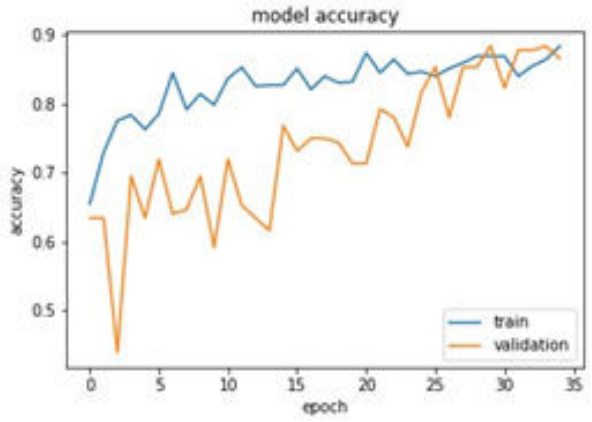
Layer (type)	Output Shape	Param #
conv2d_7 (Conv2D)	(None, 128, 128, 32)	896
max_pooling2d_7 (MaxPooling2	(None, 64, 64, 32)	0
batch_normalization_7 (Batch	(None, 64, 64, 32)	128
conv2d_8 (Conv2D)	(None, 64, 64, 64)	18496
max_pooling2d_8 (MaxPooling2	(None, 32, 32, 64)	0
batch_normalization_8 (Batch	(None, 32, 32, 64)	256
conv2d_9 (Conv2D)	(None, 32, 32, 128)	73856
max_pooling2d_9 (MaxPooling2	(None, 16, 16, 128)	0
batch_normalization_9 (Batch	(None, 16, 16, 128)	512
conv2d_10 (Conv2D)	(None, 16, 16, 256)	295168
max_pooling2d_10 (MaxPooling	(None, 8, 8, 256)	0
batch_normalization_10 (Batc	(None, 8, 8, 256)	1024
conv2d_11 (Conv2D)	(None, 8, 8, 512)	1180160
max_pooling2d_11 (MaxPooling	(None, 4, 4, 512)	0
batch_normalization_11 (Batc	(None, 4, 4, 512)	2048
global_average_pooling2d_1 (	(None, 512)	0
flatten_2 (Flatten)	(None, 512)	0
dense_7 (Dense)	(None, 200)	102600
dropout_5 (Dropout)	(None, 200)	0
dense_8 (Dense)	(None, 50)	10050
dropout_6 (Dropout)	(None, 50)	0
dense_9 (Dense)	(None, 2)	102

Total params: 1,685,296
Trainable params: 1,683,312
Non-trainable params: 1,984

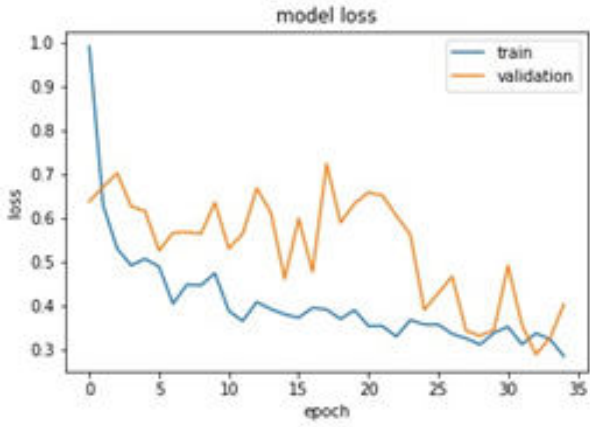
Figure c - Model Summary

EXPERIMENTAL RESULTS AND DISCUSSION

The model was trained for 35 epochs and the best results were obtained at the 34th epoch without overfitting. The best training accuracy obtained was 86.57% and the best validation accuracy obtained was 88.41% for the 34th epoch.



Graph 1 - Model Accuracy



Graph 2 - Model Loss

Out of the 40 testing images, in the result, true positives were found to be 18, true negatives were found to be 15, false positives were found to be 5 and false negatives were found to be 2. Precision of the model was 78%. Recall of the model was 9% and the F1 score of our model was 83%.

CONCLUSIONS

Our aim in this paper was to reduce the false negative images. Analyzing the test results, we can conclude that, our model has comparatively less number of false negatives. Hence, the target of our project is achieved.

FUTURE SCOPE

We have developed a model to recognize the presence of staircase to help the visually impaired people. We can deploy a similar model for the recognition and directional indication of escalators. Such a model can tell whether an escalator is

moving vertically upwards or downwards and how far the escalator is from the visually impaired person. The accuracy of the same can be checked and improved.

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