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Stair Detection and Classification Using Deep Neural Network for the Visually Impaired

Ashwini Gaikwad[1], Dr. Vinaya V. Gohokar[2], Dr. Rupali Kute[3], Bhakti Paranjape[4]

MIT World Peace University, Maharashtra, Pune, India.

ashwini.barkade1@gmail.com
vinaya.gohokar@mitwpu.edu.in
rupali.kute@mitwpu.edu.in
bhakti.paranjape@mitwpu.edu.in

Abstract—
Stair case detection is very challenging task for visually impaired people. It plays very important role to avoid accidents. Detecting stairs are comparatively easy but classification of stair case as up and down is a complex task. The literature survey more focuses on classifying up stair cases. However, detection of downstairs is also more important for visually impaired. The paper presents work done in the field of stair case detection for visually impaired people custom dataset of stairs up and down is prepared. The images are taken under various light conditions and background. It mainly focuses to detect up and down stairs using a different pertained model and comparative performance analysis is presented. The fine-tuned VGG-19 pretrained deep learning model gives better performance.

Index Terms—Stairs detection, Stairs classification, Deep learning, Custom dataset, Faster R-CNN ResNet50V1, VGG-19.

I. INTRODUCTION

As stated by world health origination, globally at least 2.2 billion people have a near or distance vision impairment [16]. In India 15 million people are visually impaired [18]. It is very difficult for them to carry out their daily tasks and they require support to do these tasks. When visually impaired people come at the age group of 60-80 these problem becomes more serious for injury and death. Amongst all the daily tasks stair case detection and classification is one of the most important areas in research for visually impaired people to avoid accidents.

Stairs are of many types and shapes. These different varieties of stairs become more dangerous if it is not correctly detected or classified. Therefore, detection and classification are the most important tasks to avoid accidents. Visually impaired people may fall if stairs are not correctly classified. Already many devices are designed as Helmet, low weigh stick, smart cap and more models developed using latest technologies for visually impaired people to make their life more comfortable.

In this paper the stair case detection is done using deep neural network. Faster R-CNN Resnet50v1 pretrained model is used. The designed model detects up and down stair condition with high score. Deep neural network is used to achieve high accuracy. Deep neural network has many features in application areas such as defense, medical, automatic driving car etc. It provides features like object

recognition and detection, image classification, face recognition and detection. For classification of stairs as up and down VGG19 pretrained convolution neural network is used.

For this research custom dataset of stair case is created using Google's open image dataset v6, some images are downloaded from internet and some images are taken from the surroundings. These all images are labeled and given as an input to the pretrained model. Stair case detection model is trained using pretrained Faster R-CNN Resnet50v1 and staircase classification is done using VGG19 pretrained model.

The organization of paper is as follow, section 2 describes the literature review. Section 3 describes the proposed work of the system. In section 3.1 stair case detection proposed work is described and in section 3.2 describes the proposed work of stair case classification. Section 4 describes the experiment and analysis of staircase detection and classification. Section 5 describes the conclusion of the paper with future work.

II. LITERATURE REVIEW

Deep learning techniques are used to design a model which can solve complex problems. Deep learning provides many features like online newspaper paper reading, image captioning, face and text detection and recognition, object detection, drug pill recognition system. In many systems to improve accuracy of the system deep learning algorithms with pretrained networks are used. Md. Ahsan Habib, Md. Milon Islam et al. [1] developed hybrid system using sensor. Faster R-CNN Inception-v2-COCO model is used for the system for both upstair and downstair detection. And achieved accuracy of 98.73%. Low weight stick using ultrasonic sensor for staircase and manhole detection is developed by sreenu ponnada et al [2]. Bivariate Gaussian Mixture Model is used for both upstair and downstair detected with 88% of accuracy. Anderi ciobanu, Anca Maorar [12] developed real time stair case detection on mobile device using structure sensor. Staircase detection algorithm is used for detection and only upstairs are detected. Ascending order stairs and location of stairs are detected from the images by Sara Carbonara, Cataldo Guaragnella [15]. Researchers used characteristic frequency spectrum method for this model. Camera system on helmet is developed by Hannes Harms, Eike Rehder et al. for real time assistance for visually impaired people. Only ascending stair detection is done with good accuracy. Anurag Ramteke, Pradip K. Das et al. [4] using convolution neural network different types of full and partial stair case detection is done using GPS and pixel information. Python environment is used to develop the model. And achieved classification accuracy of 89.74%.

From this literature survey, it is seen that different techniques and algorithms are used to detect staircase. But there is less work done on detection and classification of both upstairs and downstairs. In this paper the research is done to design model for both detection and classification for both upstairs and downstairs using deep neural network. Faster R-CNN ResNet50V1 pretrained model is used for staircase detection. And for Up and down staircase classification VGG-19 pretrained model is used. Different pretrained model like Xception, MobileV2, VGG16 and VGG-19 were used for classification for performance analysis and comparison. Model obtained good results using VGG-19 and achieved accuracy of 83% for classification.

III. PROPOSED METHODOLOGY

The two proposed methodologies, A. Staircase Detection B. Staircase Classification is explained in the following sections.

A. Staircase Detection

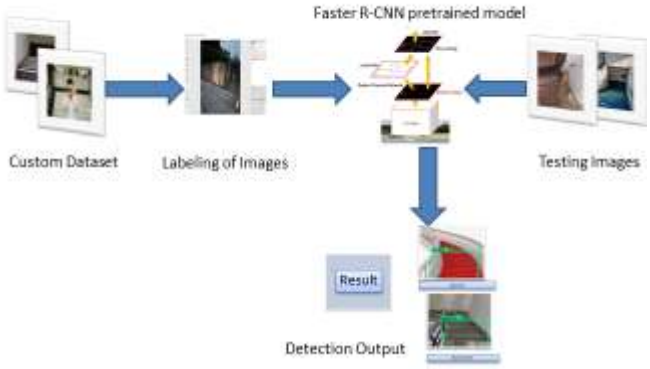

Fig. 1. Block Diagram of Staircase Detection System

Block diagram of staircase detection is shown in figure1. Input for this system is set of staircase images. Custom dataset is created. Dataset is labeled using labeling application. It is popular and user friendly application. In this application labels are saved in .xml file format of PASCAL VOC which is a popular format. This dataset contains upstairs and downstairs images. Labeling is done for upstairs images as 'upstair' and downstairs images as 'downstair'. Sample image labeling in labeling as shown below. Training is done using this labeled dataset. For training Faster R-CNN ResNet50V1 pretrained model is used. After completing the training, model is tested by giving test images. At the output stage upstair and downstair detection results are obtained.

Fig. 2. Image Labeling.

1) Faster R-CNN ResNet 50 V1

Faster R-CNN is improved version of Fast R-CNN. Region proposal and convolution models are used in Faster R-CNN. Faster R-CNN contains two modules. First model is deep fully convolutional network and second module is Fast R-CNN detector that uses the proposed regions. Faster R-CNN is faster than Fast R-CNN. Faster R-CNN is one of the most accurate algorithms for object detection. The architecture of Faster R-CNN is shown below.

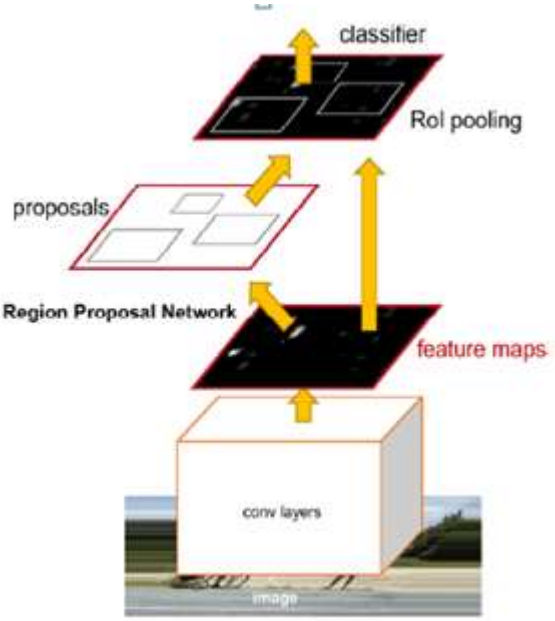

Fig. 3. Faster R-CNN Architecture [17]

Model is trained using Faster R-CNN ResNet50v1 pretrained model. This model is trained on COCO 2017 dataset. COCO is a large dataset which has serval features: object detection, recognition and segmentation. The images are scaled in 640x640 size in Faster R-CNN ResNet50 v1 model. Faster R-CNN with Resnet-50 (v1) initialized from ImageNet classification checkpoint [20].

B. Staircase Classification

The block diagram of staircase classification is shown below

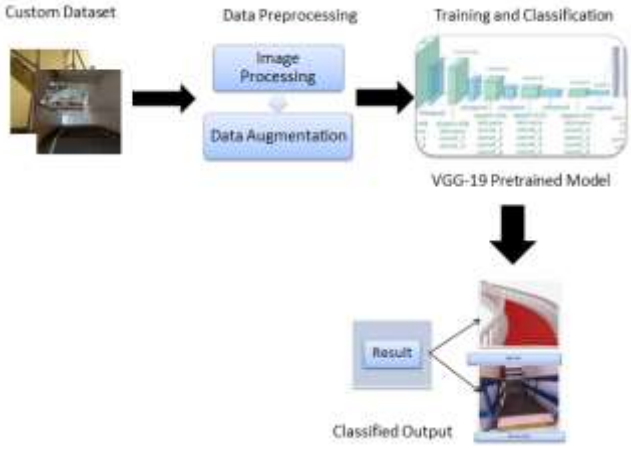

Fig. 4. Staircase Classification Block Diagram.

The block diagram shows the staircase classification model to classify upstair and downstair. Custom dataset is created and pre-prossed to make dataset suitable for our model. There are different pretrained models are available for image classification like VGG-16, ResNet50, Inceptionv3, EfficientNet etc. We are trained our model using different pretrained model like Xception, MobileV2, VGG16 and VGG-19. Analysis is made from these models. From analysis, VGG-19 is used which gives good results. Model is tested by giving test images and output is observed. The model is correctly classified upstair and downstair images.

1) Pretrained Models

VGG-19: VGG19 is a 19 layer deep pretrained model. It is an improved version of VGG-16. It is trained imageNet dataset. It can classify large number object category of images like people, pencil, animals. Input size for this model is 224x224. VGG-19 is used as both feature extraction and fine tuning. The architecture of VGG-19 is shown below,

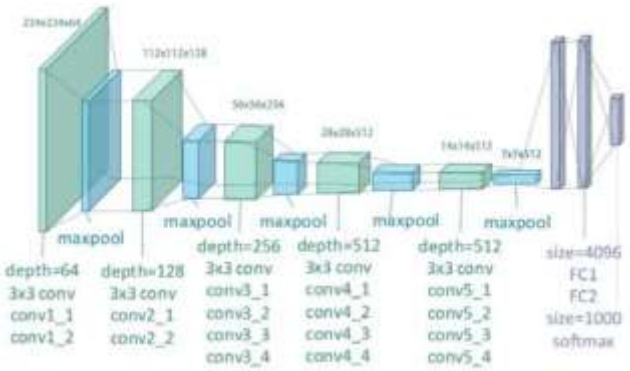

Fig. 5. VGG-19 Architecture [3].

VGG-16: VGG-16 is 16 layer deep convolution neural networks. This model is used for classification and detection. The model achieves 92.7% top-5 test accuracy in ImageNet, which is a dataset of over 14 million images belonging to 1000 classes [18]. The architecture of VGG-16 is shown below. Input image size required for this network is 224x224 RGB images. There are some drawbacks of VGG-16, it is slow to train and weights in network architecture are larger so more disk space required.

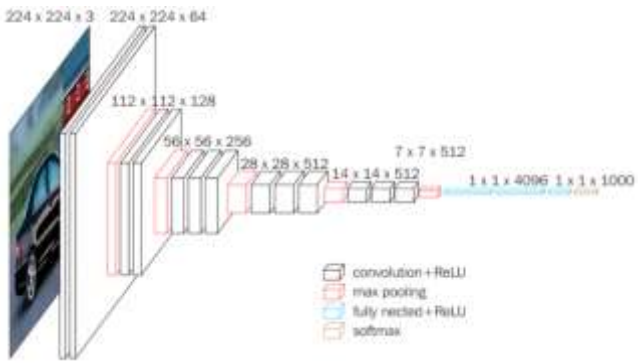

Fig. 6. VGG-16 Architecture[18]

MobileNetV2: MobileNetv2 works well for mobile devices or any device which has low computational power. It is most important pillar for feature extraction .It is also widely used for object detection and segmentation. The architecture of MobileNetV2 is shown below.

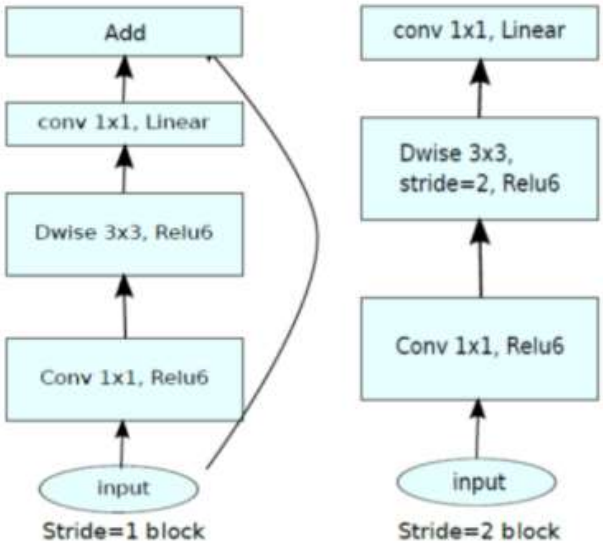

Fig. 7. MobileNetv2 Architecture [13].

Xception: Xception is deep convolution neural architecture that involves depth wise separable convolution. Xception is based on architecture of inception model. Stander inception model is replaced with depth wise separable convolutions. The architecture of xception model is shown below. In this model first data flows in entry level. After entry level it flows in middle level and repeated eight times and finally in exit flow.

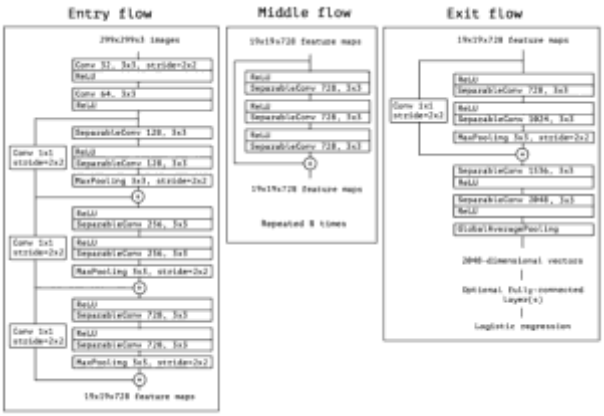

Fig. 8. Xception architecture [13].

IV. EXPERIMENTS AND ANALYSIS

Once the model is trained, we get detection and classification results on test set. Experiment is performed for two categories A. Staircase detection B. Staircase classification. Availability of staircase dataset in already existing dataset was checked. As it was not available, custom dataset

was created. The staircase dataset is downloaded from Google's open image v6 dataset, internet and some images of residential buildings. Images are resized to 227x227 sizes for less processing time. Below figure shows some sample of custom dataset images which are collected for staircase detection.

Fig. 9. Sample of custom dataset images.

Data augmentation: In deep learning applications large number of data is required. For our system to get larger dataset some image processing function is applied for which color transform and flipping functions have used. Custom dataset is divided into training and testing sets. Model is trained on this training dataset. Trained model is tested on the testing dataset. Also output analysis is done using testing dataset.

A. Staircase Detection:

Stair case 'Upstair' and 'Downstair' condition is detected by the system with high score. Using Faster R-CNN ResNet50v1 model is trained while training there is loss at each step. When training start loss is high and it get decreases during training progress. We stopped our training at 20 K steps. At this step minimum loss is obtained. Training time required is 2-3 hours for 20 K steps. In figure 9 shows loss at each step. Staircase detection output is shown below figure 10.

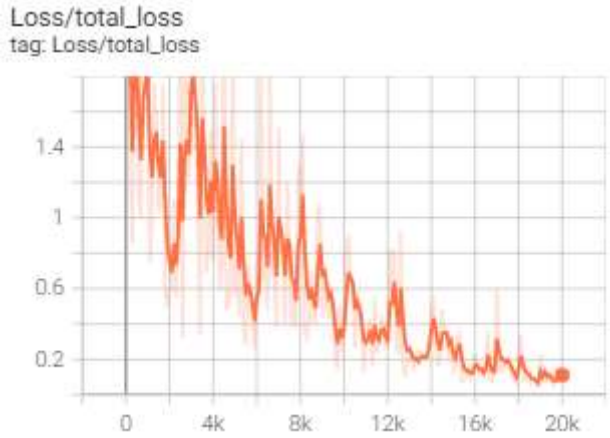

Fig. 10. Graph of total loss during each iteration.

Fig. 11. Staircase Detection.

B. Staircase Classification:

Model is trained using different pretrained model like Xception, MobileV2, VGG16 and VGG-19. This trained model is applied on test set and analysis is done. Classification report shows the accuracy, precision and recall obtained by models.

Performance analysis is done on following parameters. Model is correctly classify upstair and downstair is represented by True positive(TP) and True negative(TN) while model is incorrectly classified upstair and downstair is represented as False positive(FP) and False negative(FN). Performance metrics parameters, definition and equations is explained in below table,

Table 1. Performance metrics

Performance Metrics	Definition	Equation
Accuracy	It is ratio of number of stairs prediction done correctly to total number of prediction made.	$\frac{TP + TN}{TP + FP + TN + FN}$
Precision	It is ratio of correctly predicted positive stairs to total number of positive result obtained.	$\frac{TP}{TP + FP}$
Recall	It is ratio of correct stairs prediction outcomes to the actual results obtained.	$\frac{TP}{TP + FN}$
F1-Score	It is the average of precision and recall. Higher the F1-score better is the performance.	$\frac{2 \times (Recall \times Precision)}{Recall + Precision}$

All performance metrics accuracy, precision, recall and f1-score obtained using different pretrained model is shown in classification report. VGG-19 model gives high accuracy 83 % and it is more efficient and accurate. Classified images of upstair and downstair is shown in below figure,

Fig. 12. Classified Images.

Table 2. Classification Report

Sr No	Model	Precision (%)	Recall (%)	F1 Score (%)	Support
1	VGG-19				
	Upstair	82	82	82	50
	Downstair	83	83	83	54
	Accuracy			83	104
	Macroavg	83	83	83	104
	Weightedavg	83	83	83	104
2	VGG-16				
	Upstair	90	73	80	62
	Downstair	69	88	77	42
	Accuracy			79	104
	Macroavg	79	80	79	104
	Weightedavg	81	79	79	104
3	MobileNetV2				
	Upstair	68	94	79	50
	Downstair	91	59	72	54
	Accuracy			76	104
	Macroavg	80	77	75	104
	Weightedavg	80	76	75	104
4	Xception				
	Upstair	67	92	77	50
	Downstair	89	57	70	54
	Accuracy			74	104
	Macroavg	78	75	73	104
	Weightedavg	78	74	73	104

V. CONCLUSION

In this paper stair case detection using deep neural network for visually impaired people is proposed. For visually impaired people classify stair as up and down is difficult. In this paper detection and classification is done. Faster R-CNN ResNet50v1 pretrained model is used for staircase detection. Model is detected upstair and downstair with high accuracy. VGG-19 pretrained model is used for staircase classification as upstair and downstair. The developed model achieved detection accuracy of 99% and classification accuracy of 83%. The working flow and architecture of the system is explained well with proper diagrams and tables. In future, this model can be used for real time stair detection with some danger alarm system .This alarm system become more user friendly for visually impaired people for indoor and outdoor stairs detection.

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