Mapping of Sri Lankan Road Signs by Using Google Street View Images

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***Abstract*—The development of autonomous vehicle driving systems and Intelligent Transportation System (ITS) have been able to draw massive attention since the 1980s. For the development of ITS, road sign detection and identification are considered to be very important due to the vital information provided by road signs. Generally, real-time video-based methods are used as the source of images for the operation of ITS. But they are inefficient and costly due to certain limitations like weather conditions, lighting conditions, and limited range in obtaining quality images. To overcome those limitations of the video-based approach, this research aims on developing techniques for the detection and identification of road signs by using Google Street View (GSV) as the image source, OpenCV for image processing and CNN for road sign identification. EdleNet, LeNet-5, and DenseNet were identified as accurate CNN models. By using images from GSV, it was possible to generate a database of road signs with the relevant coordinates, which is currently unavailable in Sri Lanka. In addition, this process leads to the generation of a valuable image dataset of Sri Lankan road sign images, and a web interface with mapped road signs. Consequently, this research would yield useful findings that may be applied to future research and provide the means to develop ITS, accident-avoidance systems, and driver assistance systems.**

Keywords—Google Street View (GSV), Google Directions API, intelligent transportation systems, machine learning, road sign detection and identification

I. INTRODUCTION

Traffic signs provide valuable information to drivers and other road users. They are essential to ensure safety by conveying some message to the drivers and pedestrians in a non-verbal manner [1]. This will help to maintain discipline on the road which will lead to minimize the possibility of accidents up to some extent.

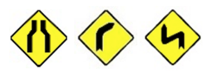
Most road signs consist of some easily understandable pictures rather than words. As a result, it is simple to understand, and people who speak different languages may also readily grasp the concept. All the drivers and pedestrians should know what each road sign represent to avoid serious accident or fines. Road sign come in a variety of shapes and colours which differs from one country to another. The use of different shapes and colours helps to identify a sign quickly without interrupting the driving.

Road signs can be categorized as follows [2]:

1. Danger warning signs
2. Regulatory signs
   I. Priority signs
   II. Mandatory signs
   III. Restrictive
   IV. Prohibitory signs
3. Directional informative signs

Generally, each of these categories is represented in different colours or shapes for ease of understanding. TABLE I shows the composition of Sri Lankan road signs.

TABLE I. MAJOR TYPES OF SRI LANKAN ROAD SIGNS

Type	Count	Shapes	Colours	Examples
Danger warning signs	55	Square	Yellow	
Regulatory signs	64	Circle, Octagonal	Red rim, Red	
Directional informative signs	55	Square	Blue	

Many studies have been undertaken in recent years in the field of road sign detection, and identification around the world. In Sri Lanka, there has been some research on a video-based system that has used Convolution Neural Network (CNN) to detect road signs and inform drivers as a voice message using a text-to-speech engine [3].

By taking a different approach, this research aims to develop techniques for the extraction, detection, identification, and positioning of traffic signs by using GSV images along any selected route for a very low cost, low effort, greater accuracy, and reliability [4]. Unlike the video-based approach, this process can be fully automated and completed within a very less time.

The objectives of the research could be specifically identified as follows:

1. Detection and identification of traffic signs using GSV images as image source.
2. Save the extracted information in a database.
3. Mapping of identified road signs in a web interface.
4. Preparing a highly extensive public image dataset of Sri Lankan road signs.
5. Usage of the extracted information for advanced applications.

The rest of the paper would be discussed in the following manner. Section II would cover the related works. Section III explains the research methodology. Section IV discusses the results and discussions. Finally, in section V, the research's conclusion is stated.

II. Literature Review

The literature review is discussed under three main sections, Downloading of GSV images, Road sign detection, and Road sign identification.

A. Downloading of Street View Images

GSV imagery is considered to be the world's most extensive and also the most geographically extensive street perspective imagery database. It has been providing this service since 2007 [5]. The GSV images database can be accessed using Google Maps static Application Programming Interface (API) through HTTP requests. There is a daily limit of 25,000 image requests and 2,500 directions (One query may generate 100 directions, so 250 queries per day) [6]. And user-defined parameters such as the image size, image location, heading, pitch, and scale can be used to access a selection portion of the 360° panorama available in GSV [4].

Meanwhile, the Google Directions API is used to plan a route on Google Maps between given start and end locations. This will return a JSON routes array with intermediate legs and steps or in an XML element. The steps and legs will be used for accessing the available GSV images. There were some object detection researches which were using GSV images to detect utility poles. For that, a tool called ArcGIS has been used for the generation of viewpoints along roads at 10m intervals and then those points have been used for downloading images from GSV [7].

B. Road Sign Detection

Road sign detection is a crucial challenge, especially for applications involving automobile safety. The majority of road sign detectors are built based on the application of the gradient map of the input image to a geometrical model of the road sign border. There are three types of approaches for it: Single Pixel Voting (SPV) schemes, Contour Fitting (CF), and Pair-Wise Pixels Voting (PWPV) schemes [8]. And there is a new technique for detecting road signs called the Fast Shape-based method. It is more effective and reliable in identifying triangular, square, and octagonal road signs. This technique determines potential shape centroid locations in the image with the use of symmetry in the shapes along with the pattern of edge orientations which are then displayed by equiangular polygons with a known number of sides. The location and the size of the detected shape are returned by this method [9], [10].

Without requiring a colour model and even when they are unclear to determine, certain object detection techniques have introduced a novel transform for the simultaneous detection of angle vertex and angle bisector which has been successfully used for triangular road sign detection. It has been able to quickly process a 360×270 image in under 50 ms [11]. Further in some research, the road signs are detected by using colour clues and by carrying out some geometric property analysis. For segmenting the image and looking for items consisting of similar colours, the system starts by clustering the colour features. To eliminate pointless objects and keep the candidate Region of Interests (ROIs), these segmented regions are compared to various potential characteristics of a road sign, like the size or aspect ratio. The ROIs are then divided into various shape groups by using a unique shape classification technique. It will help to weed out any candidates that actually do not belong to any of the acceptable shape groups [12].

C. Road Sign Identification

CNN is the prominent deep learning technique used in computer vision applications. Neural Network (NN) is basically a mathematical model which is based on the primitives of neurons. A large number of artificial neurons are networked into different layers to build up a deep neural network. It will accept vectors as inputs and will pass through the layers of the network while predicting the output. CNN consists of three main types of layers namely convolution, pooling, and fully connected layers [3].

DenseNet121, DenseNet161, DenseNet169, and DenseNet201 are four dense CNN-based models that are specifically used for the road sign identification process. In DenseNet-121 each layer connects deeply with all other layers in the network. DenseNet-201 is a deep convolutional neural network consisting of 201 layers. DenseNet-161 and DenseNet-169 are some versions of the Dense Neural Networks models which are developed with 161 and 169 layers respectively [13]. The enhanced LeNet-5 model is a similar road sign identification model composed of 7 layers taking into account the SoftMax output layer [14].

III. Methodology

The proposed methodology consisted of downloading of street view images, road sign detection, road sign identification, and mapping road signs in a web interface as illustrated in Fig 1.

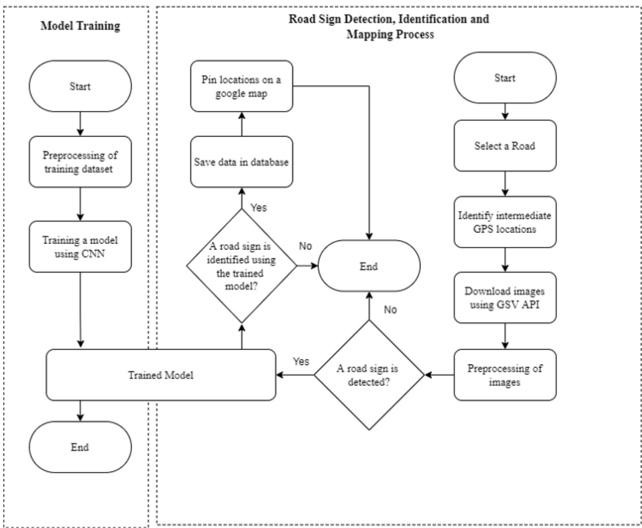


Fig. 1. Flowchart illustrating the road sign mapping process.

A. Downloading of Street View Images

GSV images are used for the detection of road signs in this research. Initially, the intermediate points between two given locations are found by using the Google Directions API. The google maps and datetime Python libraries are used for this operation. It is possible to obtain direction-related data for several modes such as transit, driving, walking, or cycling through this API. The origin and destination are given as parameters to obtain the polyline of the path. Later the polyline is converted into an array of coordinates with the help of the "polyline" Python library.

Next, the images are downloaded through GSV API by providing a Uniform Resource Locator (URL) which includes the suitable parameter information [7].

Required parameters for the URL:

- API key
- Size (output image size)
- Pitch (the up or down angle)
- Fov (horizontal field of view angle)
- Heading (cardinal direction in the range of 360°)

As a tool to interact with the API easily, the "streetview" Python package was used [15]. Initially, panorama IDs corresponding to the coordinates are requested and in the case of unavailability, the process will be repeated by obtaining the nearest available panorama IDs [16].

The daily request limit of GSV API is 25,000. And up to 500 GSV images can be downloaded in a maximum resolution of 2048×2048 pixels and only a maximum resolution of 480×480 pixels is allowed in the free version [6]. To make the process much simpler and reliable, four images are obtained for one viewpoint under different headings (0°, 90°, 180°, and 270°)

B. Road Sign Detection

Fig. 2. illustrates the complete road sign detection process.

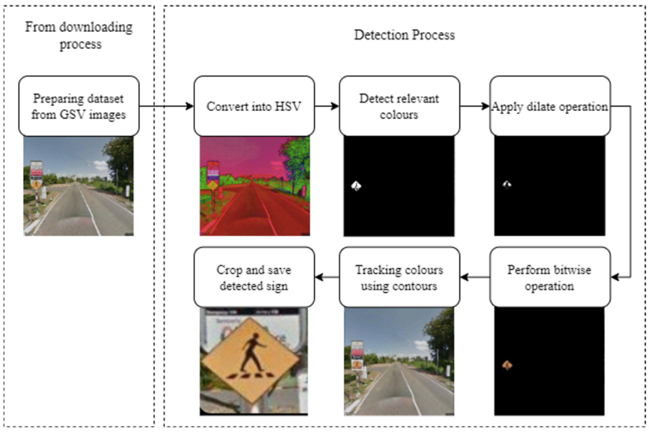


Fig. 2. Complete road sign detection process.

Road signs are detected based on two main features such as colour, and area of detected contours. The steps of detection can be briefly stated as,

- Detection of contours based on the most common road sign colour ranges, and
- Filter results based on the area of the detected contours.

TABLE II shows the Hue, Saturation, Value format (HSV) colour ranges of the three main colours (Red, Blue, and Yellow) which were used for the detection process. These ranges were manually extracted by using a colour picker program.

TABLE II. HSV Colour Ranges Used

Colour	**HSV Ranges**	
	Lower	***Upper***
Red	[0,114,140]	[7,196,204]
	[5,26,209]	[13,60,255]
Blue	[96,140,0]	[111,228,255]
	[83,69,144]	[101,255,255]
Yellow	[14,149,91]	[25,255,255]
	[18,23,214]	[37,44,255]
	[14,136,137]	[18,215,217]

As the first step, the image is transformed into the HSV. Next, the dilation operation was performed to enhance the object area features. Then based on the HSV ranges, contours are isolated from the image and cropped by using image processing as a part of the automated process.

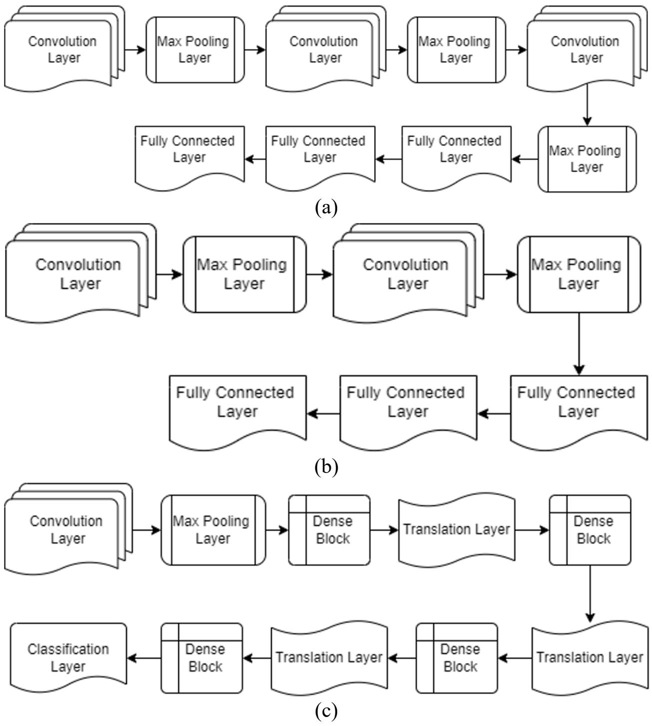


Fig. 3. Layer diagram of CNN models. (a) EdelNet, (b) LeNet-5, (c) DenseNet.

C. Road Sign Identification

Several road sign identification models were chosen to test the accuracy for choosing the most suitable CNN model for the identification process. Below are some highly accurate models that are specified for the road sign identification process [17]–[19]:

1. EdleNet
2. LeNet

3. DenseNet

Fig. 3. depicts the layer arrangement of each of these identification models.

Before testing, and training the model, the images were preprocessed using grayscale and equalize methods [20]. And further, augmentation of images was performed to obtain a more generic dataset for training.

D. *Mapping of Road Signs in A Web Interface*

A web interface was implemented to display the identified road signs. React JavaScript library (https://reactjs.org/) was used for front-end web developments. Road sign data will be fetched from the MySQL database consisting of the information of road signs and the relevant coordinates. By using that information, the mapping of road signs will be performed in a web interface. It will be an overlay to the existing google maps, hence all other information in google maps will retain while only the road signs will be displayed additionally.

IV. RESULTS AND DISCUSSION

The results and discussion is discussed under four main sections, namely, downloading of GSV images, road sign detection, road sign identification, and mapping in a web interface.

A. *Downloading of Street View Images*

Images were downloaded under four different headings for a given longitude and latitude. Fig. 4. displays a sample set of images downloaded for a set of coordinates in different heading angles.

Fig. 4. Sample images at longitude = 81.84842, latitude = 7.29632 for (0°, 90°, 180°, and 270°) headings.

During the process of downloading, a total distance of 285.05 km was covered with a total of 70,888 images, under 9 different routes in Sri Lanka as shown in Fig. 5.

B. *Road Sign Detection*

An accuracy of 95.89% was achieved for the road sign detection process. Also, as a by-product of the detection process, a dataset of Sri Lankan road signs belonging to 12 different categories was produced. Fig. 6. depicts a selection of sample detections obtained using the detection procedure.

The first and second rows show some successful detections where a road sign is cropped at the end of the process as shown in column (c). And the third row shows a false detection where a pedestrian crossing has been detected as a road sign, due to the availability of similar colours and areas in the surroundings. Such false detections can be properly identified and terminated in the identification step.

C. *Identification of Road Signs*

TABLE III contains the accuracy of the models that were considered for the identification of road signs with the corresponding accuracies [17]–[19]. The German Traffic Sign Recognition Benchmark (GTSRB) has been used for training the model [21]. The maximum accuracy of 99.75% was found to be in the EdleNet model.

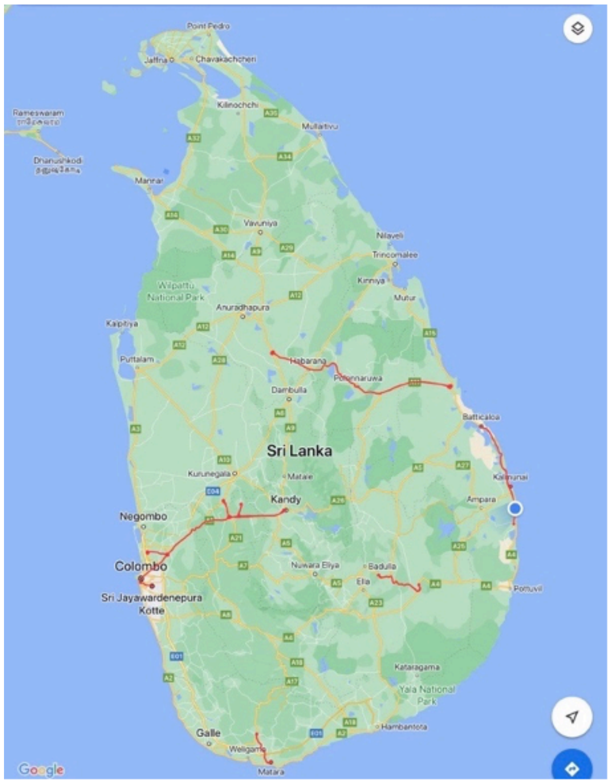


Fig. 5. Map displaying the downloaded routes using GSV.

(a) (b) (c)

Fig. 6. Sample road sign detections (a) original image, (b) rectangular bound, (c) cropped road sign.

TABLE III. ROAD SIGN IDENTIFICATION MODELS USED

Model Name	Dataset	Accuracy(%)	No. of layers
EdleNet	GTSRB	99.75	9
DenseNet	GTSRB	99.02	10
LeNet-5	GTSRB	92.44	7

(a) (b) (c) (d)

Fig. 7. Sample road sign correct identifications in (a) Stop sign, (b) Pedestrian crossing ahead, (c) Bus stop, and wrong identification in (d) Pedestrian crossing as bus stop.

Fig. 7. depicts a selection of sample identification obtained using the identification procedure. There are some cases as shown in the image (d), where there pedestrian crossing is wrongly identified as a bus stop due to the similarities in the image and reduced clarity with the distance to the road signs. However, the identification process can be carried out with a greater degree of accuracy with the specialized models in TABLE III, in the presence of a good image dataset for training. It can be easily obtained as a by-product of the detection process.

D. Mapping in A Web Interface

As the initial test route, the Kalmunai to Akkaraipattu Route was selected. And the complete process was performed for that particular route. The Fig. 8. displays the developed web interface with few of the marked road signs.

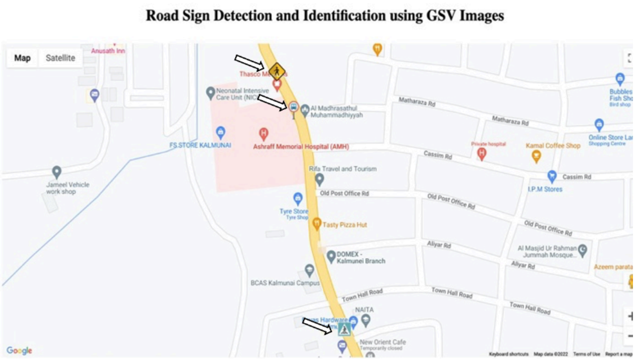


Fig. 8. Developed web interface with the mapping of road signs

V. Conclusion

The Kalmunai to Akkaraipattu route was chosen as the preliminary test route. Along the path, 1128 images were downloaded using GSV, and the detection algorithm was executed. It resulted in an accuracy of 95.89%. And according to the study, among the selected models, EdleNet had the highest identification accuracy at 99.75%. During the detection and identification processes, certain false detections and identifications were observed. There are some areas that are possible for development such as developing mobile alert systems of road signs for drivers, research on the proper use of road signs to minimize road accidents, a universal database for road signs, etc. Hence this is an important and versatile area of research that could benefit many individuals. As part of future work, efforts will be made to reduce erroneous detections and identifications, extend the procedure across the rest of Sri Lanka, and finish mapping the results on the web interface.

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