Advance Driver Assistance System (ADAS) – Speed Bump Detection

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***Abstract* - In Intelligent Transportation System, Advance Driver Assistance Systems (ADAS) plays a vital role. In ADAS, many research works are done in the area of traffic sign recognition, Forward Collision Warning, Automotive navigation system, Lane departure warning system but an another important area to look through is speed bumps detection . The recognition of speed bump is a safety to a human and a vehicle. Early research in speed bump detection is done with the help of sensors, accelerometer and GPS. In this paper, a novel method is presented to achieve speed bump detection and recognition either to alert or to interact directly with the vehicle. Detection of speed bump is recognized with a help of image processing concepts. This methodology is effortless and simple to implement without the investment of special sensors, hardware, Smartphone and GPS. This procedure suits very well for the roads constructed with proper marking, and can be used in self-driving car.**

Keywords — Speed Bumps, Intelligent Transportation System, Advance Driver Assistance System, Morphological Operation.

I. INTRODUCTION

Speed bumps or speed breakers are designed in road to avoid over speed. Speed Breakers are traffic handling tool which used to slow down vehicles speed during riding [2] [8]. They are also called Speed Humps, Speed Bumps, Speed Ramps, Speed Cushions and Speed tables. Speed breakers are implemented to reduce the speed of the vehicle near schools, college, hospitals, pedestrian crossing / zebra crossing, toll gate and in some place where over speed is restricted. The Indian government has given standard norms to construct the speed bumps. But in India people are implementing speed bumps of their own which create suffering to the public. A news article highlight the presence of 12 bumps placed along 600 meters which creates inconvenience to people.

The government has given standard format and dimensionality measurement to implement the speed bumps. The authorization to construct speed bumps is under the control of Traffic Police Department and The National Highways Authority of India. Speed breakers are formed basically by providing a rounded (of 17 meter radius) swelling of 3.7 meter width and 0.10 meter height for the preferred advisory crossing speed of 25 km/h of general traffic. The illegal speed bumps lead to serious issues for patients in transit, pregnant women, person inside the vehicle and causes rapid wear and tear to the vehicles [9] [17]. Normally the speed bumps are constructed either in consecutive black and white or yellow and white stripes .The Table I shows different types of speed bumps with various dimension in terms of length, width and thickness. The dimension of the speed bump varies with respect to the roads.

This paper is organized as follows: In Section II describes the Literature Work and Section III refers the Proposed Methodology. Result and Discussion is covered in Section IV. Finally the Conclusion and Future scope are explained on Section V.

II. LITERATURE WORK

In previous work the speed bumps are detected using accelerator meter and GPS, [2] [11] [12] [14] [16] [19] [24] [25]. Add in few, research on speed bump detection was also carried using LIDAR and IR detected [1] [3] [4] [22] .Paper [2] gives the overview and detection of speed bumps using accelerometer. In paper [5] Environment-detection-and-mapping algorithms have been designed lane, pedestrian-crossing, speed-bump detection algorithms and obstacle detection algorithm using LIDARs. Nericell [18] focus on the sensing component, accelerometer, microphone, GSM radio, and/or GPS sensors. Paper [8] detected Bump based on texture variation and Hough transform and also based on local neighbourhood information.In paper [11] they propose Wolverine - a non-intrusive method that uses sensors present on smart phones. In paper [12] Jakob Eriksson, describe a system to monitor the important civil infrastructure using a collection of sensor-equipped vehicles using GPS Sensors. Paper [14] describes a mobile sensing system for road irregularity detection using Android OS based smart-phones and also in paper [6] they used three-axis accelerometer of an Android-based smart phone for safe driving. In [20], it use of a simple application for smart phones that employs two main sensors piggybacked on mobile devices a GPS receiver for vehicle's localization and a three axis accelerometer to collect acceleration data due to vehicles motion on road anomalies. The paper [21] reviews the various road conditions detection systems. And in paper [7] using image processing, it detects pothole and speed bump but they mainly focus on shadow cancelling using OpenCV. V. P. Tonde say in paper [25] about a mobile sensing system for road irregularity detection using Android OS based smart phone sensors. From the survey most of the works on speed bump detection are done with sensors, accelerometer and smart phone app [24]. The information about speed bump are collected and stored in database thus it become offline data and will not suit for the real-time scenario where as the proposed system is very well suitable for the real-time scenario. This methodology is applicable for the standalone cars without disturbing the network.

TABLE I. TYPES OF SPEED BUMPS

Type	Image sample
Type 1	
Type 2	
Type 3	
Type 4	
Type 5	

III. PROPOSED METHOD

In proposed method, captured video is converted to image, it is first preprocessed to enhance or make the image for further processing. Second process is Structural Operation which helps to identify the speed bump using morphological operation. The result of second stage is spread over horizontal and vertical projection. From the plot we can identify the presence of speed bump. The flowchart of the proposed system is shown in Fig 1.

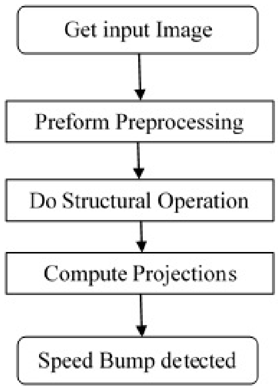


Fig. 1.The Flowchart of Proposed System

A. *Pre Processing*

Image preprocessing is the methodology to formulate the image before doing the actual computational processing. The real time sample input RGB image is shown in Fig 2. In our proposed method preprocessing involves 2 steps RGB to gray scale conversion and gray to binary conversion.

1) Convert RGB to Gray scale image: This stage includes resizing of the image to a standard size according to the requirement and convert the RGB image to gray scale image. This stage is very important since it reduce computation complexity. An RGB image is altered to gray scale image by using three different methodologies namely lightness, average, and luminosity. We consider the Luminosity. Human eyes are more receptive to green color than red and blue color so green is weighted high value than the other and the formula for computing luminosity is given by 1 and the resultant output is displayed in Fig 3.

$$L(x, y) = 0.21R(x, y) + 0.72G(x, y) + 0.07B(x, y) \quad (1)$$

Where
R – Red component of the image
G – Green Component of the image
B – Blue component of the image
x, y – position of a pixel.

Fig 2. Input RGB Image

*2) Convert the gray scale to Binary Image:*The gray image is transformed to black and white image using threshold concept. The range of threshold value can be between 190 and 255 because our focus it to separate the white region from black region. In our case, we assume the threshold value as 200 because the white painting fading due to the wear and tear on the marking. If the pixel value of the input image is above the threshold, replace the value of the input as 255 to the corresponding location and replace the pixel value below the threshold with 0 as shown in 2. This process is done not only to convert the gray image to binary and also to remove the noise like sand deposition and the noise where the road is not properly smooth.

$$\text{If } P(x, y) > 200, \text{ then } P(x, y) = 255 \qquad (2)$$

$$\text{Else } P(x, y) = 0$$

Fig 3. RGB to Gray Image

B. Structural Operation

Morphological image processing is a set of operators that transform images according to the size, shape, connectivity using the concept of set theory and other functions. This process include the following (i) Opening (ii) Area opening (iii) Filling

1)Opening operation: Opening is a structural operation which performs the erosion operation followed by dilation as shown in 3[13]. This function helps to destroy the region which is smaller than the structure element B and preserve the wider area region [15]. Thus it helps to remove the environmental noise like unsmooth road and deposition of foreign particle that leads to misclassification of the speed bump. The shape of the structure element B is considered as 'square' and size as '10' as it gives better result. The resulted image of opening is shown in Fig 4.

$$A \circ B = (A \Theta B) \oplus B \qquad (3)$$

Where

A - Input Binary image

B - Structure element

$\circ$ - Opening notation

Θ - Erosion notation

$\oplus$ - Dilation notation

Fig 4. Result of Image opening

2) Area opening operation: This stage is a refining process which helps to remove few noise that are left by opening operation and concentrate on area which has a nominal area. Opening operation is capable of removing small noise whereas Area opening will helps to remove areas which are below the specific threshold value.

3) Filling process: After completing the opening operation the next stage is filling process. It is a process of filling the gap in a white region of speed bumps evenly, because in real time most of the white regions are not perfectly painted. This stage gives better result and output at this stage is shown at Fig 5.

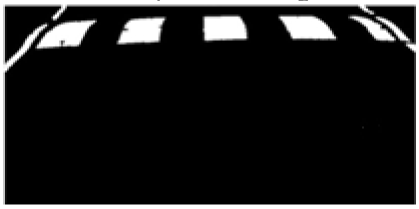


Fig 5. Result of Filling

C. Spread over Projection:

Projection is a one dimensional representation of an image computed along horizontal and vertical axis. Horizontal projection means the sum of pixel value in row wise and vertical projection is sum of pixel value column wise [10]. Horizontal projection is computed using 4 and vertical projection are computed using 5. The vertical projection helps to identify whether all the connected component region are of same size and horizontal projection helps to identify peak row position to locate the speed bump. The resultant output at this stage is shown in the following Fig 6 and Fig 7.

$$P_h(v_o) = \sum_{u=0}^{M-1} Y(u, v_o) \quad for\ 0 \le v_o < N, \qquad (4)$$

$$P_v(u_o) = \sum_{v=0}^{N-1} Y(u_o, v) \quad for\ 0 \le u_o < M, \qquad (5)$$

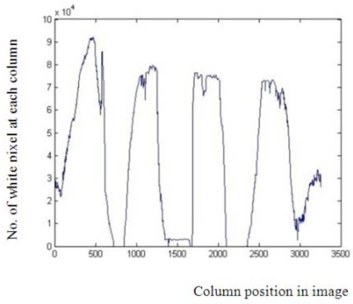


Fig 6.Result of Vertical projection

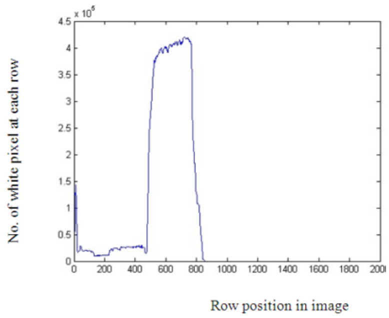


Fig 7. Result of Horizontal Projection

IV. RESULT AND DISCUSSION

To analysis each category of speed bump many real time images were captured in and around the roadside of India. The performance measure taken here is Accuracy rate which is a ratio between numbers of speed bump detected correctly to total number of input image. The most common Speed bumps pattern falls under the category Type 1, Type 2 and Type3.Type 1 and Type 3 are similar in pattern but the variation lies on the dimension. As displayed in Table II Type 1 dataset consists of 300 images which are taken in clean roadside whereas Type 3 are roads with varies dimension, sand deposition and improper road construction. In real time, there are many speed bumps with various length, width and thickness but most properly the pattern followed is the same that of zebra crossing. So the proposed method is suitable for all speed bumps designed with zebra crossing pattern.

TABLE II. ACCURACY RATE OF DIFFERENT SPEED BUMPS

Image Type	Total no of input image	No of speed bump detected correctly	No of speed bump missed	Accuracy Rate
Type 1	300	270	30	90%
Type 2	250	212	38	85%
Type 3	200	166	34	83%
Type 4	70	56	14	80%
Type5	50	2	48	4%

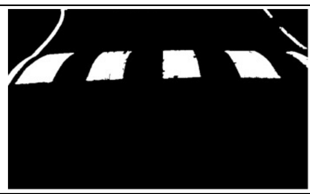
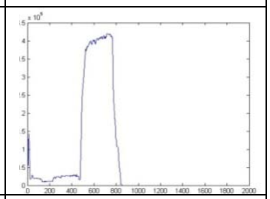
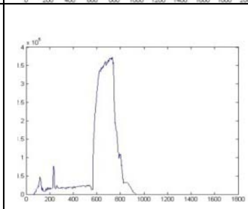
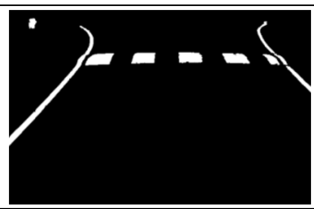
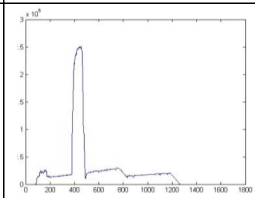
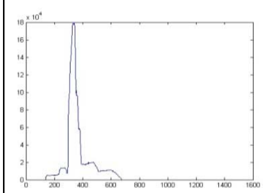
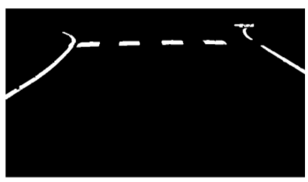
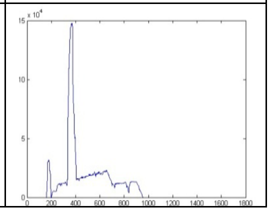
Type 4 speed bumps are very rarely constructed .While speed bumps of Type 5 is very common in rural area and also in some residency area where this kind of speed bump is unlawful. The proposed method suit very well for all type except Type 5 speed bump. Type 2 is a special case where the colors are yellow and white instead of white and black. The overall average accuracy rate is 84.5% excluding type 5.Table III show the result of horizontal and vertical projection with respect to distance. At various distance the horizontal and vertical projection are calculated. In the result we compute the parameter called Horizontal projection Height, Horizontal projection width, Vertical projection height, Vertical projection width and number of pattern. In analyzing the HP height is maximum at 10 feet and minimum at 50 feet. Thus when we are nearing to the speed bump the height of the HP pulse gets increased. And coming to horizontal pulse width the pulse width is 390 at 10 feet and 210 at 20 feet, 110 at 30 feet, 90 at 40 feet and 60 at 50 feet explaining that, when the speed bump is far the vertical pulse width is less and get swell as we near to speed bump.

TABLE III. HORIZONTAL AND VERTICAL PROJECTION VALUES WITH DISTANCE

Distance	HP Average Height	HP Pulse Width	VP Average Height	VP pulse Width	Number of similar pattern in VP
10 feet	4.25×10^5	390	7.5×10^4	600	3
20 feet	3.8×10^5	210	5.8×10^4	350	3
30 feet	2.5×10^5	110	2.8×10^4	200	3
40 feet	1.6×10^5	90	1.5×10^4	170	4
50 feet	1.3×10^5	60	1.25×10^4	120	4

Table IV show the graphical representation of horizontal projection containing the height and width. Here the X-axis refers the row position of the image and Y – axis refers the number of white pixel at each row position. This methodology can predict the presence of speed bump at 50 feet itself thus alerting the driver and result in safe driving.

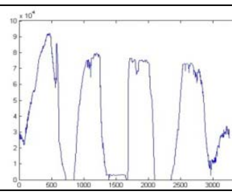
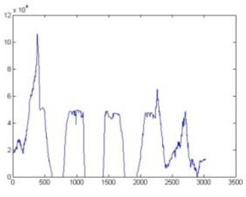
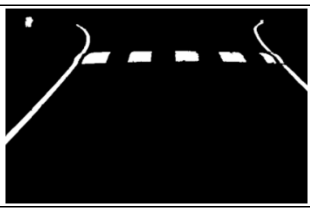
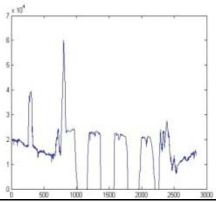
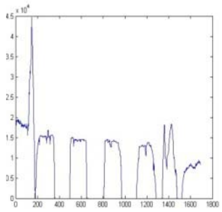
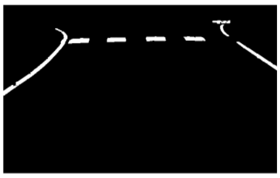
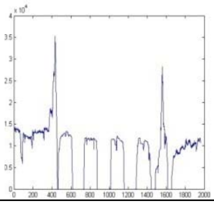
TABLE IV . IMAGE HORIZONTAL PROJCETION AT VARIES DISTANCE

D (feet)	Projection Input Image	Horizontal Projection
10		
20		
30		
40		
50		

The vertical projection which is analyzed gives us addition support in identifying the speed bump. Vertical projection pulse width is 120 at 50 feet, 170 at 40 feet, 200 at 30 feet, 350 at 20 feet and 600 at 10 feet thus clearly showing that width of each pulse is enlarged as we go near to the speed bump. The peak point of each pulse is also increased when we move from the distance ranging 50 to 10 feet. The graphical representation of vertical projection is shown in Table V where the X-axis refers the column position of the image and Y – axis refers the number of white pixel at each column position Finally we look into the similar pattern parameter, since speed bump follows a same white pattern we can easily distinguish speed bump from other obstacles or false alarm based on the number of similar pattern. When the number of pattern is more than 2 we can conclude the presence of speed bump.

Further as advancement the results can be trained using neural network so that it can efficiently detect the presence of speed bump even from long distance without the help of sign board.

TABLE V. IMAGE VERTICAL PROJCETION AT VARIES DISTANCE

D (feet)	Projection Input Image	Vertical Projection
10		
20		
30		
40		
50		

V. CONCLUSION AND FUTURE SCOPE

In this paper the speed bumps that are constructed with standard norms can be easily recognized and the system alerts the driver. This methodology can be embedded in higher end vehicle and especially self-driving cars .The average performance of the system considering only speed bump with proper marking is 85%. This methodology does not need any external hardware, sensors and smart phones. Without congesting the GPS network and disturbing the mobile battery we can easily detect the speed bump. The future scope of the work focus on detecting speed bump during night time, detecting speed bumps which do not follow any pattern or marking, training the speed bump detection using neural network concept and finally to distinguish zebra crossing with speed bump.

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