Speed-bump Detection using Otsu's Algorithm and Morphological Operation

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Abstract— Driver assistance system is one of the vital Subsystems of Intelligent Transport system. Speed-bump detection is a system that helps to identify the presence of speed-bump and alter the driver or operate on the vehicle directly. The Speed-bump is detected using two methods i) Otsu's threshold method and ii) Morphological Operation method. Compare to the existing method. The proposed method gives better performance in terms of Detection rate. Morphological or structural operation method achieve 79 % detection rate.

Keywords— Advanced Driver Assistance system, Speed-bump Detection, Otsu's Algorithm, Morphological operation

I. Introduction

Speed-bump detection is essential because many accidents are happening due to sudden intrusion of a speed-bump. An un-notified speed-bump on high speed is harmful to patients in transit like pregnant women. It also leads to rapid wear and tear of tyres and even damages the vehicles. This system is developed to alert the driver in advance about the presence of a speed-bump or to work immediately to reduce the vehicle speed.

II. Literature Survey

A. Speed-bump Detected using Sensor and Meter

Bret Hull et al. (2006) used CarTel - a mobile sensor computing system intended to gather, process, deliver, and visualise sensors data which is a part of mobile units. A CarTel is a mobile embedded processor linked with a collection of sensors. At each node, sensor readings are collected and processed locally before distributing them to a central portal, where the data stored for further analysis and visualisation. The automotive framework includes a variety of onboard and external sensors to collect data. The CarTel had been deployed on six cars, running in Boston and Seattle. It has been used mainly to analyse commute times, analyse metropolitan Wi-Fi distributions, and for automotive diagnostics. The goal of CarTel is to provide a simple programming interface, to handle a large amount of heterogeneous sensor data and to handle intermittent connectivity. The drawback of CarTel is that they do not offer privacy. The future scope is to develop a map-based routing application that incorporates delay information, simple routing algorithms and data analysis from OBD sensors

Choi, J et al. (2012) develop an environment-detection and-mapping algorithm for autonomous driving for both rural and off-road real-time environments. Environment-detection-and-mapping algorithms include two parts, (1) using cameras, pedestrian crossing detection, lane detection, and speed-bump detection is implemented, and (2) using LiDARs obstacle on the road was detected. VisLab Embedded Lane Detector (VELD) and a camera are used for lane detection algorithm which returns the lane location. The position of pedestrian crossings and speed-bumps are detected using the pedestrian crossing and speed-bump detection algorithms. The obstacle detection algorithm gets data from LiDARs. For the research purpose, a passenger car is designed with six LiDARs, three cameras, and personal computers. The algorithm mainly focuses on local obstacle map instead of using a global map for more accurate vehicle locating. From the collected information, the risk map and obstacle map is created by the model-based filter, which help the road users to know about the obstacles across the road.

B. Speed-bump Detected using a smartphone

Mohan, Prashanth, et al. (2008) present a system to govern road and traffic conditions. Nericell is a system established to do rich data collection by piggybacking with smartphones that people take with them. They concentrate on the sensing component, which uses the accelerometer, microphone, GSM radio, and GPS sensors in smartphone maps the speed-bumps, potholes, honking, and braking. They also address many challenges like the arbitrary orientation of smartphone, honk detection and localisation in an energy-efficient manner. The electiveness of the sensing functions using Nericell is experimented on the roads of Bangalore and produced significant results. The future scope is to work on different types of vehicles and implementing the application via machine learning to robust honk detection.

Roma Goregaonkar et al. (2013) emphasis the safety of the driver from the advanced driver assistance system. They used three-axis accelerometer built within an Android-based smartphone to record and analyse the different environmental conditions that affect the health of the driver and the automobile. In real-time, the overall awareness regarding safety is increased for drivers by analysing and alerting about the road difficulties. For accident monitoring purpose, a wireless black box using GPS tracking and GSM module is developed. GPS coordinates system, road condition maps are created via Google Earth. Besides, for a better road anomaly detection system, multiple-axis classification method is introduced, which increase the bump and pothole classification accuracy.

III. SPEED-BUMP DETECTION

Speed-bump Detection is one of the subsystems of ADAS. Speed-bumps are constructed across the road to avoid over speed in the restricted areas. If they are constructed without proper permission, dimension and representation, it leads to accidents. Speed-bump is classified into two types (i) marking speed-bump (ii) nonmarking speed-bump. The Basic block diagram is shown in Figure 1.

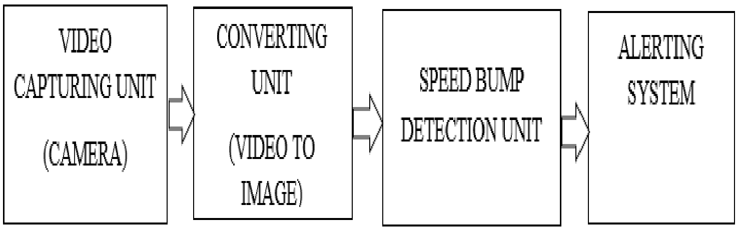

Figure 1. General Block diagram of Speed-bump Detection

The speed-bump detection unit has three stages, as shown in Figure 2. They are i) Speed-bump Identification (ii) feature extraction (iii) Speed-bump Detection. Speed-bump identification helps to find the speed-bumps in the road. Feature extraction stage extracts feature from speed-bump image and forwards to the recogniser. Speed-bump detection helps to recognise the speed-bump using an SVM classifier.

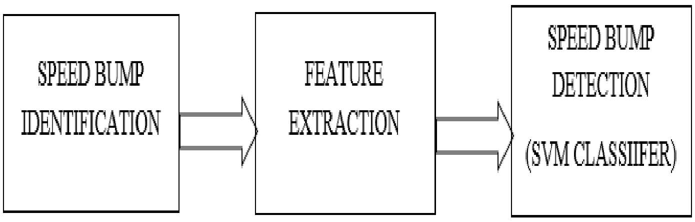

Figure 2. Speed-bump Detection Unit

A. Speed-bump Identification using Otsu's Thresholding Method (SBI – OTM)

The objective of thresholding is to segregate the region of Interest (ROI) and non-ROI. In speed-bump identification, the ROI is represented by white colour and non-ROI, is represented by black. To convert a multi-valued RGB image into a black and white image, first, it should be converted to grayscale, and then by choosing a proper threshold value, it is converted to a binary image.

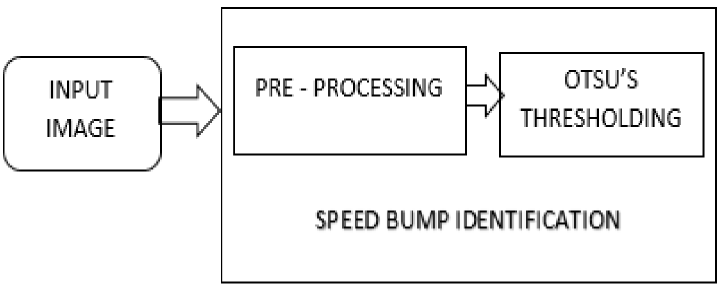

Figure 3 Block diagram of SBI - OTM

The input image is fed to speed-bump identification stage, as shown in Figure 3. Speed-bump identification includes pre-processing and Otsu's thresholding. Pre-processing contains resizing and converting of RGB image into a grayscale image.

Pre-processing, Resizing, Converting RGB to Gray Scale Image:

Image pre-processing is the methodology to formulate the image before doing the actual computational process. It includes resizing and RGB to grayscale conversion. All the input images are resized to 250×350 size. After resizing, the RGB image is converted to a grayscale image by using three different methods using lightness, average, and luminosity. Luminosity is calculated using the formula given in equation (1):

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

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.

Otsu's algorithm

This method converts the grayscale image to a binary image by performing the following steps

Step 1. Read the grayscale image.

Step 2. Compute image histogram.

Step 3. Select a threshold value and compute foreground variance and background variance

Step 4. Compute within Class variance σ_w^2 using the equation (2)

$$\sigma_w^2 = W_b\sigma_b^2 + W_f\sigma_f^2 \quad (2)$$

where W_b, W_f and σ_b, σ_f are the weights and variances of background and foreground.

Step 5. Repeat steps 3 and 4 for different threshold values T= 2,3,4, …

Step 6. For each Within-class variance choose a threshold value (T)

Step 7. If grayscale pixel value > T, assign 255 (white) else assign 0 (black)

For the different threshold value, T= 2, 3 and 4 otsu's method is applied. Among these, the threshold value T = 2 gives proper segmentation. This method is suitable only for the roads in good condition. The main advantage of this method is less computation time, but it is suitable only for dust and damage free roads.

B. Speed-bump Identification using Morphological Operation (SBI-MO)

In the proposed method SBI – MO, the input image is pre-processed to enhance or make the image ready for further processing is shown in Figure 4. The second step is to convert a grayscale image to a binary image. The third process is a morphological operation which helps to identify the speed-bump using opening, area opening and filling operation.

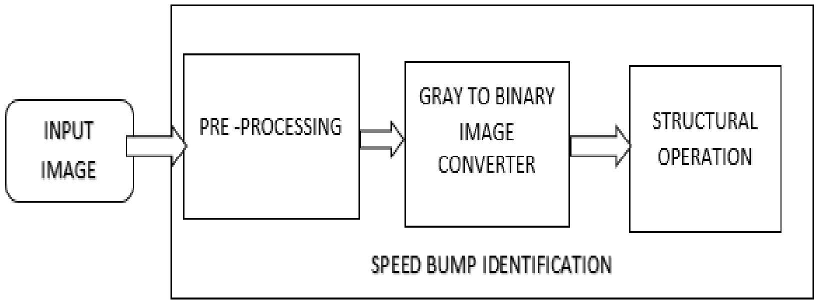

Figure 4 Speed-bump detection using Morphological operation

The grayscale image is transformed to black and white image using the threshold concept. The range of threshold value is chosen at a higher value between 190 to 255 because our focus is to separate the white region (255) and the black region(0). If the pixel value of the input image is above the threshold, the value of the pixel is replaced as 255 to the corresponding location, and the pixel value below the threshold is replaced with 0 as given in equation (3).

If $P(x, y) > 200$, then $Q(x, y) = 255$ (3)

Else $Q(x, y) = 0$

where P(x,y) refer the input pixel value at the location x,y

Q(x,y) refer the output pixel value at the location x,y

(i) 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 stage includes the following (i) Opening (ii) Area opening (iii) Filling

(ii) Opening operation:

The opening is a basic operation which performs the erosion operation followed by dilation, as shown in Equation 4. This function helps to remove the region, which is smaller than the structure element B and preserves the wider area region. The shape of the structure element B is considered as 'square' and size as '10' as it gives a better result. $A \circ B = \left(A \Theta B\right) \oplus B$ (4)

where

A - Input Binary image

B - Structure element

$\circ$ - Opening notation

Θ - Erosion notation

$\oplus$ - Dilation notation

(iii) Area opening operation:

This stage is a refining process which helps to remove further few noises that are left by opening operation and concentrate on the speed-bump area.

(iv) Filling process:

After completing the opening operation, the next stage is filling process. It is a process of filling the gap in the white region of speed-bumps evenly because in real-time, most of the white regions are not perfectly painted.

IV. Results Analysis

Computer vision method and Local neighbourhood are two existing image processing methods. In both methods, the detection rate is very less. In Otsu's thresholding method performance is slightly higher than the local neighbourhood whereas Morphological method has shown a better performance.

The output obtained for various types of images using Otsu's thresholding, Morphological operation and Gaussian filtering is shown in Table 5.3, 5.4 and 5.5. Otsu's method is well suited for the Optical illusion type speed-bump and noise-free roads. But it finds difficulty in differentiating yellow and white colour painting on a speed-bump. Thus the performance of the system is reduced. The morphological operation gives excellent performance for all type of roads. It handles noisy roads easily and yellow type marking to some extent. The identification rate of speed-bump using morphological operation is very much improved.

Table 1. Average Identification rate Comparison

	Existing Method		**Proposed Method**	
Method	**Computer vision**	**Local neighbour**	**SBI - OTM**	**SBI - MO**
Average Identification rate	50%	56%	64%	79%

For the analysis purpose, the Speed-bumps are categorised into 5 types, namely Type 1, Type 2, Type3, Type 4 and Type 5, as shown in Table 2. The most common type of speed-bump is type 1, which contains only white stripes. Type 2 is an 'Optical illusion' which is a 3D illusion of speed-bumps launched to fake the drivers in order to slow down on roads. This is a future type of speed-bump. Type 3 is a kind of speed-bump similar to type 1 but with a noisy environment. Type 4 includes all the other pattern other than stripes like arrow shape, chessboard shape. Type 5 category has white with yellow marking on them.

For specific speed-bump category, several real-time images are captured in and around Indian roadside the analysis. The performance measure taken here is identification rate which is the ratio between numbers of speed-bumps detected correctly to the total number of input images. Table 3 and Table 4 gives the identification rate attained by the two proposed methods. It also contains a total number of samples, count of speed-bump identified correctly, count of speed-bump missed and the Success rate in percentage is given for comparison. The variation of speed-bump is seen in terms of their pattern, colour, length, width and height. In this work, categorisation of speed-bump is done only based on colour and pattern irrespective to their dimensionality.

V. Conclusion

In ADAS Speed-bump detection is a critical subsystem. In this paper, speed-bump is detected using Otsu's Threshold Method and Morphological operation method. Compare to Otsu's method, and the morphological method gives a better result. The future scope of the work is to detect the speed-bump without marking and recognising using neural Network.

Table 2. Comparison of Output proposed method

Types of speed-bump	Input Image	Output Image of SBI-OTM	Output Image of SBI - MO
Type-1 Only White stripe			
Type -2 Optical illusion			
Type -3 Noisy Image			
Type - 4 Others pattern			

Type -5 Yellow stripe			

Table 3. Identification rate comparison of various types of speed-bumps using Otsu's Thresholding Method (SBI – OTM)

Image Type	Nature of speed-bump	Total No. of input images	No. of speed-bumps identified correctly	No. of speed-bumps missed	Identification Rate %
Type 1	Only White stripe	884	612	272	69.23
Type 2	Optical illusion	50	35	15	70.00
Type 3	Noisy Image	446	307	139	68.83
Type 4	Others pattern	254	134	120	52.76
Type5	Yellow stripe	214	130	84	60.75

Table 4. Identification rate comparison of various types of speed-bumps using morphological operation (SBI - MO)

Image Type	Nature of speed-bump	Total No. of input images	No. of speed-bumps identified correctly	No. of speed-bumps missed	Identification Rate %
Type 1	Only White stripe	884	713	171	80.66
Type 2	3D	50	42	8	84.00
Type 3	Noisy Image	446	334	112	74.89
Type 4	Others pattern	254	198	56	77.95
Type5	Yellow stripe	214	176	38	82.24

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