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An Approach for Real-Time Road Deformation Detection using Image Processing

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ABSTRACT

Wearing out of roads which causes cracks and potholes is a serious, commercially very expensive, time consuming and such an issue, that it not only can, but indeed always results in road mishaps, fatal accidents and so on. Also it is an issue which keeps on growing as the time ticks, which is dangerous not only to elderly or sick people, small vehicles, but also bigger vehicles with enormous damages to life and property. Potholes are risk towards road safety and travel efficiency. So there is a dire need to reduce driving hazards due to such dangerous road deformations/potholes by using Real-time detection and warning systems. In this paper, the method proposed, portrays a combination of Structured-Light generator (line laser) for plotting, measuring 2D deformations and image processing using Spectral-Clustering for rough estimation of the distress present on the road, which together will continuously monitor road for real time pothole detection.

Keywords

Deformity detection, lane detection, vision based, spectral clustering, structured light plotting.

1. INTRODUCTION

Indian roads are prone to lot potholes and cracks especially caused during rainy season and that is when a lot of people suffer. These cracks and potholes formed during rainy season continue to affect road transport throughout the year. Damaged city roads are generally reported by media personals through their channels and also by people by clicking pictures of the roads and thus the road maintenance department come in play to analyse and plan for the road repair. This is a very slow and ineffective process and by the time road repairs are deployed the road has already suffered more damage. According to Road Accident Report published by the road transport and highways ministry, in 2015 around 3416 people were killed in accidents caused due to potholes[1]. Human beings have a natural tendency to get distracted while driving vehicles which may result in incoming deformity being neglected. Hence it's better to deploy a low cost system that can continuously monitor road surface attached to the vehicle because of which the driver can be warned whenever there is a presence of serious deformity irrespective whether he/she is looking on the road or not

There are various methods for automatic detection and being developed and improved which are based on the use of expensive technologies like magnetic vibration, developing 3D reconstruction of deformity using stereo cameras. Both methods have their respective drawbacks when real time, low cost and compact design are the priorities. Magnetic method uses accelerometers and costly magnetic variation sensing system which is attached in the vehicle suspension system where the vehicle's wheels have to traverse through the deformities to detect them. Stereo cameras also need expensive laser scanners which have high computing complexity as they generate highly details image of the deformations thus requiring high cost computers.

Here the main goal is to develop an algorithm which is simple for computing in real time to achieve high speed detection, highly cost effective and compact system that can be implemented over the front top of the vehicles. Vision-based methods using key element to be camera have the potential to detected distress before the vehicle passes through it in real time. Hence the proposed method is being achieved implementing vision based approach combined with line laser light to gain effectiveness during twilight and night times and to estimate approximate depth of the deformity. Testing is being carried out to put this system in place for field trials and validation. Most of the proposed models need high configuration computers for distress detection owing to high cost. In addition to detection, the data collected from vehicles including their locations can be logged-in and shared to aid other drivers and road maintenance agencies to take evasive action if potholes are detected in real-time, since economics and time lapses are at the root of all such endeavour.

2. RELATED WORK

The study conducted for structuring this project focuses on the application of image processing for segmentation for differentiating of road defects from plain road and other surrounding objects. As mentioned earlier other two approaches are with the use of expensive stereo cameras and laser scanners for 3D reconstruction which have computing complexity and vibration based which has a few drawbacks like only the cracks and potholes will get logged from where vehicle wheels traverse through the deformities and not the ones which pass between the two side wheels. As described in paper by Emir Buza where Otsu thresholding method is used which segments images to obtain binary images from grayscale. Spectral clustering is then employed for determining shapes of irregular objects like road deformities from the selected images. In this shadows of surrounding objects and manhole covers can also get tagged as potholes and may not perform well in low light conditions[2]. AjitDanti and SeungkiRyu presented a novel approach by first using lane detection, then mapping a virtual polygon considering the lanes as sides of the polygon and then defined it as Region of Interest thus extracting a small part of the incoming video to reduce the processing load on the system and then by inspecting various features, such as the length, area, variance, and trajectory pothole extraction has been carried out. The important part in this is that not all roads have lane lines are present and in such situation by fixing lane vanishing point the unknown lane line is plotted virtually. They have implemented this is a commercially available black box camera embedded system; due to which this implementation technically faces limitation of the processing capabilities of that embedded system and also future modifications may not be possible[2 & 3]. In paper by Christoph Mertz, another novel approach by using line laser light projected on the road surface that helps in two ways: one for highly detailed 3D profiling of the road damages and other for plotting basic 2D graphical representation of the road deformations which can be well be used for filtering shadows and other objects that may get tagged as deformities which would be an improvement over the use of simple spectral clustering method [4]. But use of this system may not work effectively while in broad daylight but will generate one of the best results at night time. Thus this paper presents a combination of lane detection, laser and spectral clustering of the road for accurate detection of potholes and cracks well in advance before the vehicle passes over it.

3. METHODOLOGY

For the realization of this project, there are 3 major components being used which are a mini-low-cost computer, a high definition 1080p camera and line laser light diode. A display and a warning system consisting of LED and buzzer will be implemented to warn the driver.

3.1 Image Segmentation

Image Segmentation consists of thresholding, clustering, texture and transforms methods. The intention behind segmentation is to represent an image in something which is more meaningful and easier to analyze. In this case thresholding and spectral clustering methods will be used for filtering, determining and detecting distress regions.

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1) ROI selection:Video feed is taken from a high resolution camera, which is converted from RGB to grayscale video using formula {(0.3 * R) + (0.59 * G) + (0.11 * B)}. For contrast adjustment the grayscale frames histograms are equalized so that lane strips become brighter than the rest of the image. Lane detection algorithm works on the principle of HOUGH transformation. An array $[\rho][\theta]$ is used to count how many pixels belong to a line is done by Hough Transform as shown in figure 1. Lines having the highest pixel count are plotted on the input image and thus lane detection is performed. The two plotted lines tend to converge at a point is termed as vanishing point. Two horizontal lines are virtually plotted on the road image where one is at fixed distance from the vehicle front end and the other intercepts the vanishing point. A polygon is hence generated considering the two lane strips and the plotted horizontal lines. The coordinates of this polygon are tagged as (ROI) region of interest and are fed to the system for deformity detection process. This in turn reduces the area in each frame to be processed and also removes surrounding regions and vehicles in other lanes. For filtering out cars in the same lane car detection algorithm can be used so that system may not mistake them for being deformations.

$$\rho = x\cos\theta + y\sin\theta$$

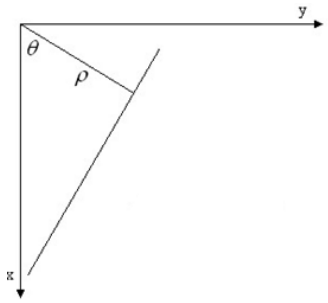


Figure 1: Hough transform for line plotting

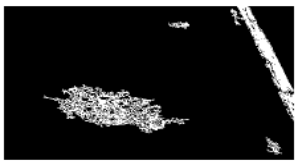
2) Thresholding: The region of interest previously determined is then processed for filtering of unwanted linear objects. In this case, Gaussian filter is first used to remove noise and then OTSU thresholding method [2], is used for converting grayscale images to binary forms based on the equation:

$$b(x,y) = \begin{cases} 1, & if\ h(x,y) \le T \\ 0, & if\ h(x,y) \ge T \end{cases}$$

Where 'T' stands for threshold value automatically generated depending on the different lighting conditions, b(x, y) is output binary image and h(x, y) is a histogram of grayscale equalized image. Thresholding is used to remove linear objects and connected shapes to the image boundary by using pixel filling method realized by inpainting function.

3) Shape extraction: This constitutes a major part distress detection where regions to be detected have highly non-convex structure or in other words the measure of the center and spread of the cluster is not a suitable description of the complete cluster. Amongst various types of clustering methods, Spectral Clustering is a best method that groups pixels with similar properties with each other and then it performs dimensionality reduction to determine shape based on chain codes as shown in figure 2 and 3. This method starts at a small point and grows to determine horizontal and vertical lengths based on 4 bit and 8 bit connectivity as shown in figure 3.

(a)



(b)

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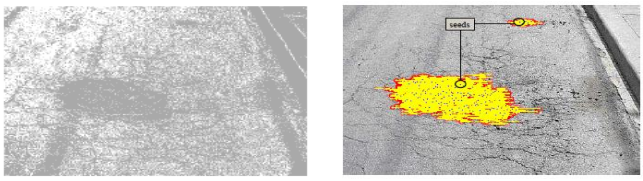


(c) (d)

Figure 2: (a) original pothole image, (b) Otsu image, (c) intermediate image, (d) clustered image[2]

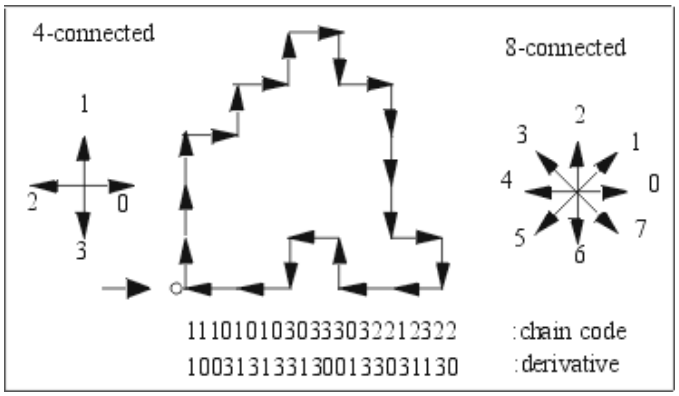
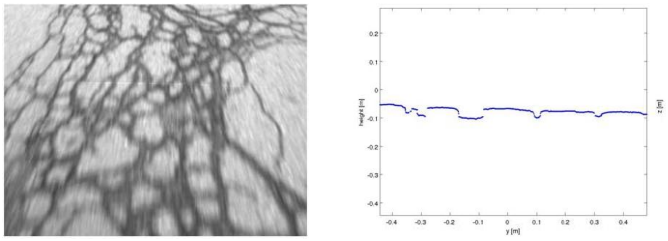


Figure 3: From left to right (a) 4 connectivity (b) example of 4 connectivity chain code, (c) 8 connectivity [5]

For processing simplicity of the algorithm, a basic precompiled cluster structure from one pothole image will be used as seed for generating faster results from the incoming video frames.

3.2 LASER

To improve the related drawbacks of the shape extraction process, a simple line LASER (Light Amplification by Stimulated Emission of Radiation) diode is used which projects horizontal line laser on the road which is captured by the camera. This laser will act as a complementary system for improving results in the low light conditions For this the input video is converted from RGB (Red, Green, Blue) color model to HSV (Hue, Saturation, and Value) color model and specifying red color range in HSV model, to extract laser light from the rest of the video frames. The extracted laser line is then plotted on a 2D (X, Y) plot using the matplotlib feature as shown in figure 4.



(a) (b)

Figure 4: (a) damaged road snapshot, (b)Laser line deformation [4]

The benefit of this is that the incident laser on the road will have constant length along the X axis and will be adjusted to remain constant at one particular value on the Y axis. Now, any deformation that is either embossed structures like speed breakers or a depressed structure as in cracks and potholes the part of laser line falling on them will deflect from the mean position on Y axis wherever the mentioned structures are present and the readings can be used to generate pothole structures in real time. The use of laser is beneficial while driving in

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twilight and night time. This method can effectively filter manhole covers from getting detected as potholes by the previously mentioned image processing. The ideal working block diagram is depicted in figure 5.

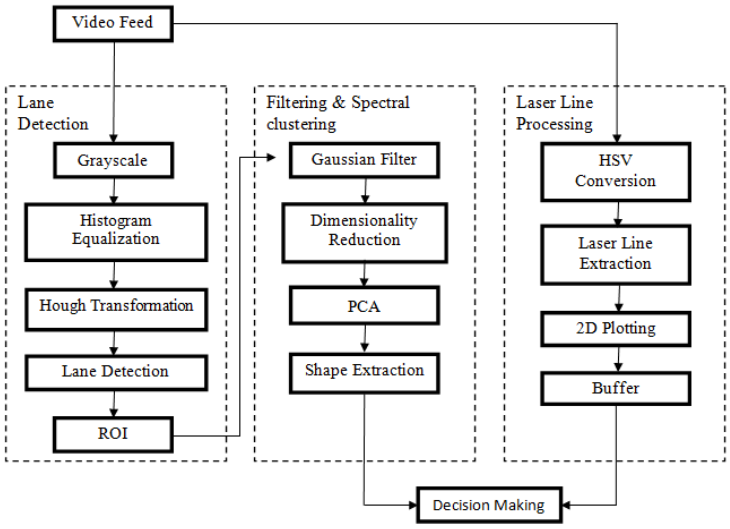

Figure 5: Overall working block diagram

This is the proposed block diagram of the system. Here, video feed from the camera will be converted into grayscale and its histogram is equalized. This is done for contrast stretching which will enhance frames. HOUGH transform function is used to detect and draw line patterns which help in determining lanes on the roads. The lanes thus detected are selected for ROI selection so that overall there is a reduction of total frame size for computing. Gaussian filter is used to minimize noise in the frames. The next major for deformity detection is PCA is used which stands for Principal Component Analysis, analyzes data for identification of patterns. This process is first aided by using Dimensionality Reduction technique which reduces the dimensions of objects with minimal loss of information. These two sections together are termed as Spectral Clustering which is the main process for deformity detections. With this the required estimated shape of deformities are obtained and depending upon their composition such as area and dimensions, the deformity is either tagged as a pothole or is discarded. LASER line light is used as complementary to the image processing which will work well in twilight and night conditions. To filter out laser line, the same video feed is converted to HSV color space where the red color is filtered and tracked based on range of red color specified. This LASER ray is plotted on 2D graph as depicted in figure 4. A buffer range is giving so as to minimize errors caused due to negligible variations on the roads being tagged. This LASER will provide extra accuracy as roadside shadow, bridge joints and manhole covers will not be tagged as deformities unlike Spectral Clustering. Combining the results from both systems, pothole detection will be carried out and accordingly, a warning in form on audio visual will be generated for the driver to be alerted.

4. IMPLEMENTATION & RESULTS

The implementation this project is carried out using OpenCV library and Python which is a simple language in comparison with C++ and Java. OpenCV stands for Open Source Computer Vision is a very efficient library of functions for image processing. Other two important packages used here are numpy and matplotlib for realizing this project

The camera will be installed in the center of front topmost location on the vehicle for the best possible view for the camera. Along with the camera, laser will be positioned besides it in such a way that the laser line falling on the road happens to be in the center of the image being captured

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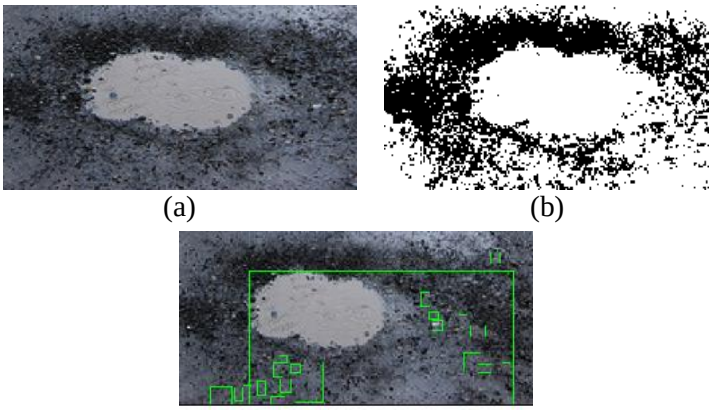
4.1 Results and discussion

The algorithm developed so far can effectively segment video frames using Otsu Thresholding and binary frames are obtained which depict road distress in black color and in white as shown in figure 6 which has an average processing time of approximate 50 milliseconds per frame.



(a) (b)

(c)

Figure 6: (a) original pothole image, (b) Otsu threshold, (c) rough pothole detection.

To improve the area to be focused for distress processing is being achieved by a lane detection algorithm based on HOUGH transform due which a polygon bounded by the main two sides resulting due to lane detection. Otsu Thresholding will enable us to remove linear and connecting structure to the heavily distressed regions. The next and important step will be to randomly select a pothole image and apply Spectral Clustering algorithm and extract the distress region thus defining it as a seed for real time detection processing. A group of pixels defining the required distress data is termed as Super pixel or Seed, which will be used on the incoming video frames to generate and detect clusters which can be effectively shown in green boxes. Along with this, this method also uses a structured line laser light to be projected on the road that will help in effectively determining road deformations during twilight and night conditions thus rectifying errors caused by Spectral clustering method caused during low lighting condition. A warning in audio visual form will be given to the driver so that he can take necessarily actions to avoid it. The development of this project and algorithm is still under process and hence definitive results are yet to be generated and determined.

TABLE 1:

LIST OF TECHNICAL PARAMETERS AND MEASUREMENTS.

Sr. no	Parameters	Measurements
1	Frames/sec	30fps
2	Resolution	720p
3	Processing time /frame	~50ms
4	Camera mounted at height	4ft
5	Max distance of detectable deformation	25meters
6	Tilt angle of camera	80^{o}
7	Speed of vehicle	~40Kmph

CONCLUSION

Thus the research and calculations being performed as per the needs, depicts thatthisproposedprojectispossibleto be implementon a system such as raspberry pi atlowcostand considerable efficiently to detect and alert drivers to slow down or steer away from regions on roads with potholes. Due to improper road lighting conditions at night, it is difficult to determine road just relying on human sight and hence the addition of LASER light for distress detection in real time will intern help such vehicle drivers to avert accidents.

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