

Analysis of Image Processing Techniques for Road Anomalies Detection

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Abstract—

This paper provides an overview and analysis of image processing concepts used for automated road anomalies detection. Several efforts have been made on past to develop a technology which may detect potholes automatically. Image processing is a vast area to be studied. Here we are reviewing the image processing techniques which are used for road network maintenance study. This paper presents the current practice of assessing road network using matlab.

Keywords— Road anomalies, Pothole detection, image processing, matlab, road anomalies

I. INTRODUCTION

Road is the main mode of transportation in India. Indian roads carry almost 90% of passenger's traffic. But roads don't sustain for a long duration of time. It requires time to time maintenance. Without maintenance roads get deteriorate quickly. Road anomalies start taking place instead of smooth road. The road anomalies are increasing due to:

- The climate change - heavy rains & snow.
- The poor drain management system.
- The increase in the traffic.
- The aged roads.
- Bad construction material

Road anomalies are crucial for safe driving. Driver faces difficulties to control the vehicle when sudden potholes or other anomalies come on the road. Inspection of the road is necessary if road accidents need to be prevented. This assessment of road is done manually by inspecting each and every road to locate the anomalies. This manually process is a time consuming with labour extensive. This review paper tells what are the current methodologies to automate this manually reviewing process of roads.

II. LITERATURE REVIEW

After reviewing many methods, this paper categorizes Automated Road Anomalies Detection System (ARADS) in 3 different types:

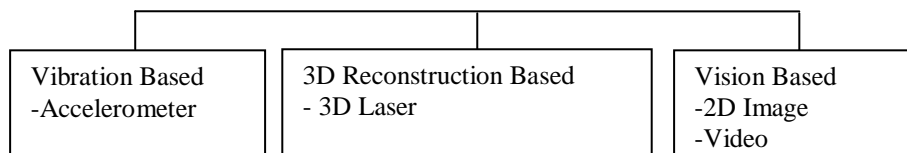


Fig 1. Automated Road Anomalies Detection Systems

A) *Vibration Based ARADS*

This method uses accelerometer in order to detect road anomalies. Accelerometer is an Integrated Circuit Board, which produces voltage signal depending on orientation to the ground and motion of it. The more accelerometer moves the higher voltage signal it produces. Accelerometer measures acceleration, vibration of cars, machines and buildings. An accelerometer based ARADS senses the acceleration and starts the data collection. These systems record and analyze the signal from an accelerometer mounted on the vehicle.

B) *3D Reconstruction Based ARADS*

This method uses laser scanner to detect the anomalies. 3D laser scanning is used to capture 3D coordinates accurately. The focused laser beam is used to scan the road surface. The reflection of laser beam pulses create digital model of existing objects. These systems record and analyze the reflection of laser beam mounted on the vehicle.

C) *Computer Vision Based ARADS*

This method uses 2 dimensional images of roads. The digital images are captured by digital cameras. The images are then digitally processed to capture the information related to the road anomalies.

III. IMAGE PROCESSING TECHNIQUES USED FOR ANOMALY DETECTION

The purpose of the study of this research paper is to present the image processing techniques used for automated road anomalies detection. The techniques are shown in the below figure:

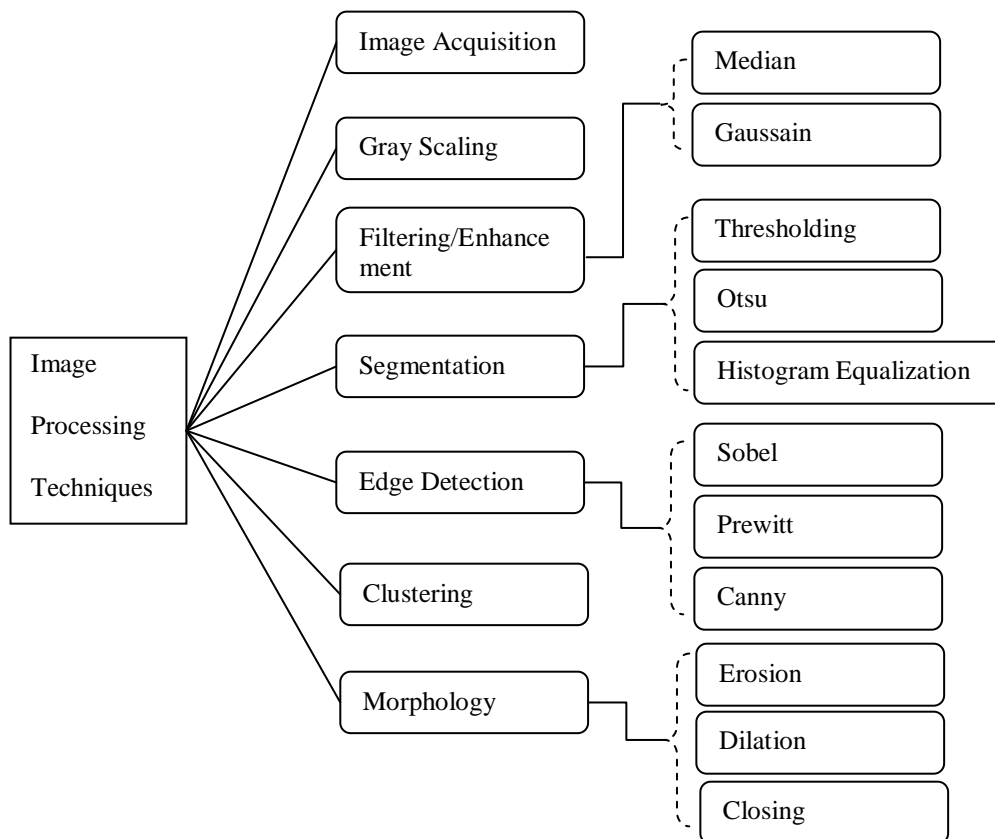


Fig 2. Image processing concepts used in automated detection of road anomalies

A. Image Acquisition

A digital camera is used to capture images or video of roads for assessment.

B. Gray Scaling

Gray Scaling is a digital image processing technique of converting RGB colored video image to grayscale image. A pixel in RGB images is a combination of three color components Red, Green and Blue. The approach to convert an image to grayscale takes the average of the intensity from each channel: $(R+B+C)/3$. The green intensity is more human oriented below weighted formula is used to for the conversion, e.g.: $0.3R + 0.59G + 0.11B$.

Matlab function for grayscaleing is $I = \text{rgb2gray}(RGB)$

[1] used the Advanced Television Systems Committee Standard $(Y = 0.2126R + 0.7152G + 0.0722B)$ to convert the image from RGB format to gray scale format.

C. Filtering

Image enhancement/Filtering is the process of removing/filtering noise from the image. Image acquisition and transmission are the main phase of image processing where noise mix in the image. The major sources of noise in the digital image are environmental conditions during image acquisition, inadequate light levels and dust particles are present on the screen. Image filtering sharpens and smoothes the image features such as edges, boundaries and adjusts image contrast to make a image more helpful for analysis.

1) *Median Filter*: Median filter is a sliding window filter which replaces the middle value in the window with the median of all pixel values in the window.

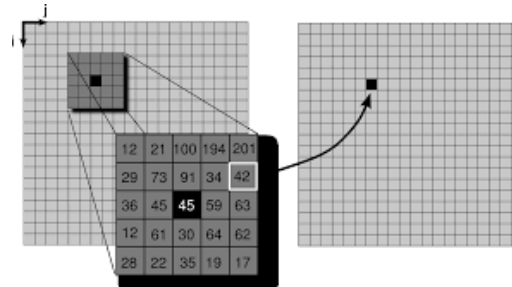


Fig 3. Median Filter

First of all, check the neighbours falling under 5X5 window keeping pixel (7, 6) in the centre. Sort the intensity values of 5X5 window.

12, 12, 17, 19, 21, 22, 28, 29, 30, 34, 35, 36, 42, 45, 45, 59, 61, 62, 63, 64, 73, 91, 100, 194, 201.

This window contains 25 pixel intensity values and the median intensity is 13th intensity value i.e 42. So, the pixel (7,6) contains intensity value 42 instead of 45. This is the way median filter works.

Matlab function for median filter is: B = medfilt2(A, [m n]).

[2] used median filter for removing random noise in images while still maintaining the overall integrity of image regions and boundaries

[3] used median filter to remove the noise of the image.

2) *Gaussain Filter*: Gaussain filter uses Gaussain equation which is convolved with the input image. The result of the convolved image is filtered image.

Equation of Gaussain filter is:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Where σ is the standard deviation of the distribution.

Matlab function for median filter is: B = imgaussfilt(A, sigma).

[4] used Gaussain filter to remove noise.

D. Image segmentation

Image segmentation is used for dividing a digital image to multiple & meaningful segments. This process converts a gray level image to binary/black & white image. This conversion takes into account a threshold values or threshold level. It converts all pixels below a threshold value to black and above threshold value to white.

Matlab function for converting image to binary image is **im2bw(I,level)**.

1) Histogram Equalization: The one way to convert the image to binary image is using histogram equalization.

Matlab function for this is histeq().

S.C Radopoulou[3] used histogram equalization to enhance the contrast of the image and binary conversion.

2) Otsu's Method: The determination of this threshold level is also done by Otsu's method of gray intensities.

Matlab function to for determining the Otsu's threshold is **graythresh(I)**.

[5] used Otsu's method to segmentation and Binarization.

E. Edge Detection

An edge is a set of pixels which are connected with each other and forms a boundary between two regions. An edge detection segments the image into discontinuous regions. There are many edge detection techniques developed in digital image processing.

1) *Sobel Edge Detection*: This technique uses 2 kernels:

Kernel for X Direction, Kernel for Y Direction, the magnitude of gradient, another formula for magnitude of gradient are respectively:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix}, |G| = \sqrt{(G_x^2) + (G_y^2)}, |G| = |G_x| + |G_y|$$

This mask let prominent the horizontal edges in an image. The 3X3 kernels are convolved with the input image. The magnitude of gradient is computed. The direction also computed.

Matlab function for Sobel Edge Detection is BW = edge(I,'Sobel').

2) *Prewitt Edge Detection*: This technique uses 2 kernels:

Kernel for X Direction, Kernel for Y Direction, the magnitude of gradient, another formula for magnitude of gradient are respectively:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & -1 \\ -1 & 0 & +1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{bmatrix}, |G| = \sqrt{(G_x^2) + (G_y^2)}, |G| = |G_x| + |G_y|$$

This mask will prominent the horizontal edges in an image. It also works on the same principle as Sobel edge detector but here Kernel's are different for x and y directions.

Matlab function for Sobel Edge Detection is BW = edge(I,'Prewitt').

[6] uses sobel and and prewitt edge detectors for image segmentation. It removes noise and gives sharp and clear edge of potholes.

3) *Canny Edge Detection*: The Canny edge detection technique contains more than 1steps to detect edges in images.

The Process of Canny edge detection algorithm can be broken down to 5 different steps:

First step uses smoothens the image by using Gaussain filter. Secondly, intensity gradients are found. After finding intensity gradients non-maximum suppression (edge thinning technique) is applied. Double threshold is applied to determine potential edges. Hysteresis thresholding is done to detect the edges.

Matlab function for Sobel Edge Detection is BW = edge(I,'Canny').

S Nienaber[4] uses canny(differentiation based) edge detector for segmentation and produce black and white image.

E. Clustering (Kmean):

k-means clustering used to partition an image into *k* clusters. Each cluster contains the observation considered for partitioning. Each cluster defines the one centre, *k* mean defines *k* centres: one for each. The algorithm calculates the mean of each cluster. Once mean is calculated, the next step is to calculate the distance of each point from each cluster. The point is assigned to the minimum distance cluster.

Matlab function for kmean clustering is `kmeans(____)`.

[7],[8] used Kmean clustering for 2 features :mean and standard deviation.

F. Convex Hull

A convex hull algorithm creates a convex region considering all the points. Here all points mean the furthest point. An example of this algorithm is shown in Figure 4.

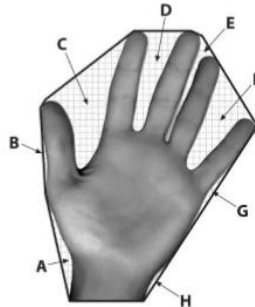


Fig4.Convex hull.

The gaps marked with points A-H are included in convex. The convex hull algorithm creates a straight line between each point and take into account entire hand.

Matlab function for this is `convexhull()`.

S Nienaber[4] uses convex hull technique to extract the road surface.

G. Morphology

Morphological image processing uses a small shape called structuring element. The structuring element can be considered like a binary sliding window passing over an image. SE can be of arbitrary or any shape and size. Below is the examples of flat SE's shapes:

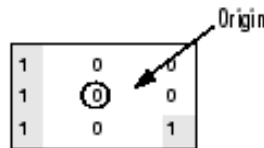
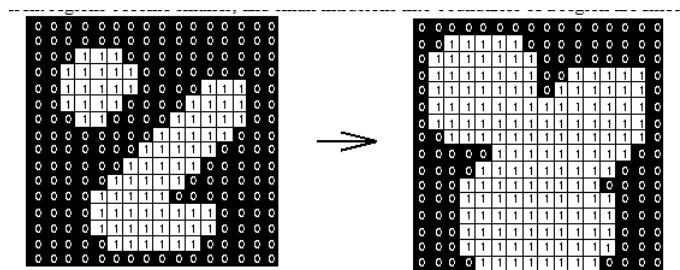


Fig.5 Structuring element

1) *Dilation*: Dilation is an image processing technique which adds pixels to the region's boundary in an image. If *f* is an image and SE is denoted by *s* then dilation can be given as

$$g = f \oplus s \quad g \text{ is the new binary image.}$$

While sliding structuring element *s* over input image *f*, SE's origin is put over the pixel of image *f* and if SE hits the input image then new image *g* contains ones in all locations(*x*, *y*). If SE doesn't hit the image *f* then the new image contains 0 in all locations.



Dilation: a 3×3 square structuring element

Fig.6.Image before (A) and after (B) dilation

Matlab function for Dilation is `imdilate()`.

[4] uses dilation to increase the area of the lighter(white) pixels. They use dilation to remove the unwanted edges close to the outer boundaries.

2) *Erosion*: Erosion is an image processing technique which removes pixels from the region's boundary in an image. If *f* is an image and SE is denoted by *s* then erosion can be given as

$$g = f \ominus s \quad g \text{ is the new binary image.}$$

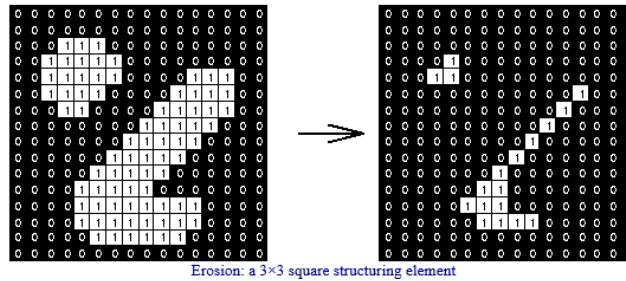


Fig.7. Image before (A) and after (B) erosion

Matlab function for Erosion is `imErode()`.

3) **Closing**: The **closing** of an image f by a structuring element s (denoted by $f \bullet s$) is a dilation followed by an erosion. Closing is so called because it can fill holes in the regions while keeping the initial region sizes.

Matlab function for Dilation is `imClose()`.

[3] uses closing to fill the holes.

H. Connected Component Labelling

Connected component labelling is the process of region extraction from an image where connected components are uniquely labelled based on given condition. Connected component groups the pixels according to the pixel connectivity.

Pixel connectivity is the way in which pixels in 2-D images connects to their neighbours. 2 type of pixel connectivity is mostly used in image processing: 4-connectivity, 8-connectivity.

4 connectivity of a pixel P contains its vertical and horizontal neighbours. 8 connectivity of a pixel P contains its vertical, horizontal and 4 diagonal neighbours.

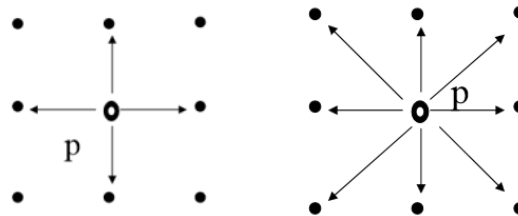


Fig.8. 4(A) and 8(B) pixel connectivity.

Matlab function for Dilation is `bwconncomp ()`.

IV. CONCLUSIONS

The purpose of this study was to give an idea to readers about the image processing techniques used for automated road anomalies using matlab. The manual detection of road anomalies is costly and time consuming task. Many efforts are made to develop a technology to assess and recognize the road anomalies.

It also tells about the matlab functions of those techniques in order to implement the automated road anomalies detection system. After studying these all methods and systems to correctly recognize the road anomalies, there is a scope to prioritize the road networks based on severity levels.

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