1. Pothole Detection: An Efficient Vision Based Method Using RGB Color Space Image Segmentation

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Abstract:

In this paper, we propose an efficient unsupervised vision-based method for pothole detection without the process of training and filtering. Our method first extracts asphalt pavements by analysing RGB color space and performing image segmentation. When the asphalt pavement is detected, the search continues in detected region only. The method is tested on online image data set captured from different cameras and angles, with different irregular shapes and number of potholes. The results indicate that the method is suitable as a pre-processing step for other supervised methods.

Keywords**:** Potholes detection, Unsupervised method, Image processing,Imagesegmentaton, Computer Vision.

The effectiveness of this method is verified on a newly formed image data set from selected images from Google search engine. The data set contains highly unstructured images taken from different cameras and shooting angles, with different irregular shapes and number of potholes. Our metod is designed for use under daytime fair weather conditions, which is consistent with a current practice.The method is low-cost and efficient since it does not requires expensive equipments , filtering nor training data. Also, the image quality does not significantly affect the accuracy.

We address the problem of automatic pothole detection by automatic analysis of selected 2D images of asphalt pavement . We propose a new unsupervised vision to detect potholes. First , we extract the asphalt pavement(region of interest) and we limit the search for pothole in that region only. The region of interest is detected through manipulation of component in RGB color space, and two-level dynamic selection of asphalt pixels(seed points) based on a standard deviationof an image. Once the asphalt pavement is found ,we proceed to detect potholes by comparing two cropped image, the idea based on the method from our previous research. The method consisit of three major steps: Image Pre-processing : image resizing, image segmentation , Region of Interest Extraction , Pothole detection

2. A Real-Time Pothole Detection Approach for Intelligent Transportation System

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Abstract:

This approach can detect potholes with lower cost in a comprehensive environment. This study proposes a pothole detection method based on the mobile sensing. The accelerometer data is normalized by Euler angle computation and is adopted in the pothole detection algorithm to obtain the pothole information. Moreover, the spatial interpolation method is used to reduce the location errors from global positioning system (GPS) data. In experiments, the results show that the proposed approach can precisely detect potholes without false-positives, and the higher accuracy is performed by the proposed approach. Therefore, the proposed real-time pothole detection approach can be used to improve the safety of traffic for ITS. The proposed real-time pothole detection method based on mobile sensing includes three steps: accelerometer data normalization, pothole detection approaches, and pothole location determination.

Pothole Detection Approaches:

The First Pothole Detection Approach: Z-THRESH
The Second Pothole Detection Approach: Z-DIFF
The Third Pothole Detection Approach: STDEV(Z)
The Fourth Pothole Detection Approach: G-ZERO
The Fifth Pothole Detection Approach: Proposed Approach

The Accuracy of Pothole Detection Approach

For the analyses of accuracy of pothole detection approach, this study selects a pothole (length: 58 cm; weight: 51 cm; and depth: 6 cm) as a case study and 10 runs in experiment environment. The mean frequency of accelerometer data detection in G-sensor in mobile device is 124 counts/second. The -fold cross-validation [13] is used to verify the accuracy of pothole detection approach. In experiments, training and testing are performed 10 times (i.e.,). In iteration , the accelerometer data in th run therapy is selected as the test corpus, and the accelerometer data in other runs is collectively used to train the thresholds for each approach. shows the comparisons of Z-THRESH approach, Z-DIFF approach, STDEV(Z) approach, G-ZERO approach, and the proposed approach. The results show that the proposed approach can precisely detect potholes without false-positives and the accuracy of the proposed approach is 100%. Furthermore, this study also implemented and compared common machine learning methods which include ANN, SVM, and decision tree (DT) Although these machine learning methods can detect potholes, several false-positives are generated by them.

3.Convolutional neural networks based potholes detection using thermal imaging

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Abstract:
Various techniques have been implemented ranging from manual reporting to authorities to the use of vibration-based sensors to 3D reconstructionusing laser imaging. But all these techniques have some drawbacks such as the high setup cost, risk while detection or no provision for night vision. Therefore, the objective of this work is to analyze the feasibility and accuracy of thermal imaging in the field of pothole detection. After collecting a suitable amount of data containing the images of potholes under various conditions and weather, and implementing augmentation techniques on the data, convolutional neural networks approach of deep learning has been adopted, that is a new approach in this problem domain using thermal imaging. Also, a comparison between the self-built convolutional neural model and some of the pre-rained models has been done. The results show that images were correctly identified with the best accuracy of 97.08% using one of the pre-trained convolutional neural networks based residual network models. The results of this work will be helpful in guiding the future researches in this novel application of thermal imaging in pothole detection field.

Keywords
Pothole detection: Thermal imaging,Convolutional neural networks,Residual networks, Deep learning

Accuracy:
Vision-based**:**Depends on the algorithm used
Vibration-based**:**High
Laser-based**:**High
Stereo imaging**:** Depends on the alignment of cameras and algorithms used

Methodolgy**:**
In this section, we present the methodology used for the proposed work. The objectives of the proposed work are as follows:
1) To find efficient and accurate CNN models for pothole detection using thermal imaging technique.
2) To evaluate the proposed technique with respect to the existing techniques.

4)Abstract:

One of the major problems faced by developing countries is the maintenance of road condition. Road infrastructure for the society is very important because majority of road accidents takes place due to bad condition of road like potholes. Potholes are caused due to poor quality and badly maintained roads. The constant movement of the overweight vehicles like trucks is also responsible for these ill roads. These ill quality roads will cause severe damage to the vehicles in terms of tyre and most important thing is the accidents which are caused due to this. An optimal system should be developed to monitor the road condition and analyses for future work. We propose an innovative method to prevent these hazards by using the advanced sensor system. The sensors will be attached to vehicles and from vehicles the data's obtained from sensors and the location obtained by the GPS are transferred to road transport authority by IOT where officials take necessary actions. Using the data's obtained more damaged area can be prioritized and damage control can be reduced.

Sensor is a device used for detecting and measuring GPS and accelerometers without any input data from the of physical property and records, indicates or otherwise user. It sends these data's to the server.A simple in-cloud response to it. in simple words they are used to detect meta classifier is used to find out if a significant number events or changes in environment and send it to a data's from users passing through the same location controller. there are **three types of sensors**

i) analog
ii) determines the pothole or not. The decision of the metadigital
iii) pwm. There are list of different sensors which classifier is stored in the database and published on the fall under either of these types. website. this method was capable of detecting 90% of the The **GPS** (Global Positioning System) is a potholes in the road. "constellation" of approximately 30 well-spaced satellites Dong-Won Jang [1] proposed a new spatio-temporal that orbit the Earth. It is possible for people to pinpoint saliency that detects the objects coming closer to the their geographic location. The accuracy is anywhere from vehicle such as potholes using a dash-cam installed in 100 to 10 meters for most equipment. A GPS system works cars. Using directional filtering the saliency of the pothole by receiving at least three satellite signals to calculate is enhanced. It only reports the presence of potholes but latitude and longitude and the movements. When GPS not pothole position for repairs. gets signal from four or more satellite then a 3-D position Sudarshan S. Rode, *et al* [13], proposed a system in can be viewed ie latitude longitude and altitude

Method: The ultrasonic sensor is used to detect the potholes on road. It is detected and indicated with voice IC sensor The LCD display is used that will display the presence of pothole on road. Voice IC will play the voice for few seconds.

5)Abstract:

Theroad irregularities and roughness due to bad maintenance are significant cause for road accidents in India. Road users often feel uncomfortable whenthey drive on rough roads,especially due to potholes. Thispaper presents a pothole detection system using the concepts of IoT. A mobile application "ROAD MODE "isdeveloped that shows details of upcoming potholes so that driver can plan his safety and avoid badroads It serves as a tool in monitoring issues related to road conditions by using sensor IOT and incorporating data analytics for future work.

ARM Development Board

Zigbee Transmitter and receiver
GPS Module
Vibration Sensor
Accelerometer Sensor
GPS Module will detect the location of map of cracks on road.
Vibration Sensor will sense the pothole.

I.IMPLEMENTATION1.The system consists of a device that is designed by integrating an accelerometer, GPS with help of an Arduino Board. 2.The designed device is attached to the rim of thewheel. The accelerometer can be utilizedto detect dynamic force like vibrations due to its high sensitivity to a very small change too. This method is not only feasible but flexible i.e. can be used in any environment (on any vehicle) just by changing the sensitivity of the device. 3.The overall system is cost effective and highly reliable in terms of accuracy. It forms an intelligent system which operates without any human intervention and reduces reliance on manual methods for maintenance of record and detection. 4.Accelerometer in conjunction with GPS module is an innovative approach to design an efficient system to map all the damaged roads all across the globe. 5.The coordinates, obtained when the vehicle encounters a pothole, is sent to the server that uses an algorithm to classify the pothole based on its severity and stores it in the database.6.These coordinates are used to display the locations and the severity of the potholes on the mapping application.Figure 1: Working of the systemFigure 2: Screenshot of the mapping applicationFigure 3: Screenshot of the mapping applicationFUTUREWORKANDCONCLUSIONThe system provides a two way interface to update and access the data regarding any possible irregularity on the road. This will be an important tool to avoid accidents in the place where the risk of accident or injury is substantial.

6)AN AUTOMATIC ROAD DISTRESS VISUAL INSPECTION SYSTEM USING AN ONBOARD IN-CAR CAMERA(Thitirat Siriborvornratanakul Graduate School of Applied Statistics, National Institute of Development Administration (NIDA), 118 Seri Thai Rd., Bangkapi, Bangkok, Thailand)

Abstract:
The goal of this project is to study and develop a low cost,easy to use,nondestructive automatic road inspection system. They have considered 3 main characteristics while detection & classification of road distress i)Dimension ii) On surface pattern iii)On surface location and orientation .They used image-based pothole detection algorithm which consists of following steps-1)Preprocessing 2) Detecting 3) Grouping,clustering. But this detection algorithm still includes false alarms which can be improved.

7)ASPHALT PAVEMENT POTHOLE DETECTION AND SEGMENTATION BASED ON WAVELET ENERGY FIELD. (Asphalt Pavement Pothole Detection and Segmentation Based on Wavelet Energy Field Penghui Wang, Yongbiao Hu, Yong Dai, and Mingrui Tian) National Engineering Laboratory for Highway Maintenance Equipment, Chang'an University, Xi'an, China

Abstract:
In this paper,a pothole detection & segmentation method based on wavelet energy field is proposed. (This is unlike automatic pothole detection methods ie 3 D reconstruction & 2 D vision based methods which are expensive). The wavelet energy field effectively integrates the grayscale & texture information together,which can accurately detect pavement pothole. This is a vibrational based method .The method has been implemented in a MATLAB prototype & achieves high detection &

segmentation accuracy. Pothole detection steps :-1)Wavelet decomposition 2)Wavelet coefficient modules calculation 3)Construct wavelet energy field 4)Morphological & geometric judgement.

Pothole Segmentation steps:-
1)Construct Markov Random field model
2)Pothole segmentation
3)Morphological processing
4) Edge extraction
This method is very accurate still false detection exists.

8)Image based pothole detection system for ITS Service and Road Management System

(Image-Based Pothole Detection System for ITS Service and Road Management System
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Abstract

In this study ,a pothole detection method based on two-dimensional(2D)images is proposed for improving the existing method and designing a pothole detection system to be applied to Intelligent Transportation System (ITS) service and road management system. For experiemnts,2D road images that were collected by a survey vehicle in korea were used.A 2D image based approach has been focused only on pothole detection and is limited to a frame ,so it cannot determine the magnitude of potholes for assessment.
The proposed method can be divided into three steps
1)Segmentation
2)Candidate region extraction
3)Decision .
This method has an overall accuracy of 73.5%.There are some limitation in this method.Potholes may be falsely detected according to the type of shadow and various shapes of potholes.Thus in order to more accurately detect potholes,it is necessary to use images from not only a single sensor but also additional sensors .

9)Image-Based Pothole Detection System for ITS Service and Road Management System (

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Abstract:

A pothole is defined as a bowl-shaped depression in the pavement surface, and its minimum plan dimension is 150?mm
Existing methods for pothole detection can be divided into vibration-based methods, three-dimensional (3D) reconstruction-based methods, and vision-based methods
The proposed method can be divided into three steps:
i)segmentation,
ii)candidate region extraction
iii) decision histogram used for extracting dark regions for pothole detection

candidate regions decision is made whether candidate regions are potholes or not by comparing pothole and background features. The segmentation step is to separate a pothole region from the background region by transforming an original color image into a binary image using the histogram of an input image. HST (Histogram Shape-Based Thresholding), maximum entropy, and Otsu [28] can be used for this transformation into a binary image. The candidate step involves extracting a pothole candidate region from a binary image obtained in the segmentation step. First, the median filter is used to remove noise such as cracks and spots. , , and filters were tested and the filter showed the best performance among the three filters. Next, the damaged outlines of object regions are restored, and small pieces are removed using the closing operation (dilation and erosion) of a morphology filter. A square () type of the structure element was used for the closing operation.After the closing operation, candidate regions are extracted using features such as size, compactness, ellipticity, and linearity, as shown inwhere : the value of region for the candidate in the image, : the size of region in the image after the closing operation, : the compactness of region in the image after the closing operation, : the threshold for size, and : the threshold for compactness. Total number of pixels in the region which depends on a size of a pothole, Incomplete candidate regions are refined using the convex hull operation according to the decision of where : the value of refined region for the candidate in the image, : the value of region for the candidate in the image, : the center position ofregion , : the compactness of region in the image, and : the threshold for compactness. Next, MHST (modified HST) separates not only the pothole region but also a bright region, such as a lane marking, from the background region. The decision step involves deciding whether the refined candidate regions are potholes or not after the comparison of candidate regions with the background region using features such as standard deviation and histogram. if the standard deviation of the refined candidate region is smaller than the threshold for standard deviation or if OHI of the pixels between the refined candidate region and the background region is close to 1 and the OHI of values using the Sobel operation [30] is close to 1, it is decided that the refined candidate region is not a pothole because it is similar to the background region Two-dimensional images with a pothole and without a pothole extracted from the collected pothole database (a total of 150 video clips) were used to compare the performance of the proposed method with that of the existing method [20] by several conditions such as road, recording, and brightness conditions.To collect video data of potholes, the newly developed optical device (resolution 1280 × 720, 60?f/s) were mounted at the height of a rear-view mirror of a survey vehicle, and they recorded the road surfaces ahead during movement.The proposed pothole detection method was implemented in Microsoft Visual C++ 6.0. The image processing was performed on a laptop (Intel Core i5-4210U, 2.4?GHz, 8?GB RAM).TP, correctly detected as a pothole), false positives (FP, wrongly detected as a pothole), true negatives (TN, correctly detected as a nonpothole), and false negatives (FN, wrongly detected as a nonpothole) [19] was counted manually. Also, accuracy, precision, and recall using the proposed method and the existing method were calculated as measurements for validation:

(1)accuracy: the average correctness of a classification process - (TP + TN)/(TP + FP + TN + FN)
(2)precision: the ratio of correctly detected potholes to the total
number of detected potholes - TP/(TP + FP)
(3)recall: the ratio of correctly detected potholes to actual potholes - TP/(TP + FN).

accuracy of 73.5%, with 80.0% precision and 73.3% recall.

10)Pothole Detection, Reporting and Management using Internet of Things: Prospects and Challenges(International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-5 Issue-1, November 2017 1 Published By: Blue Eyes Intelligence Engineering & Sciences Publication Pvt. Ltd.)

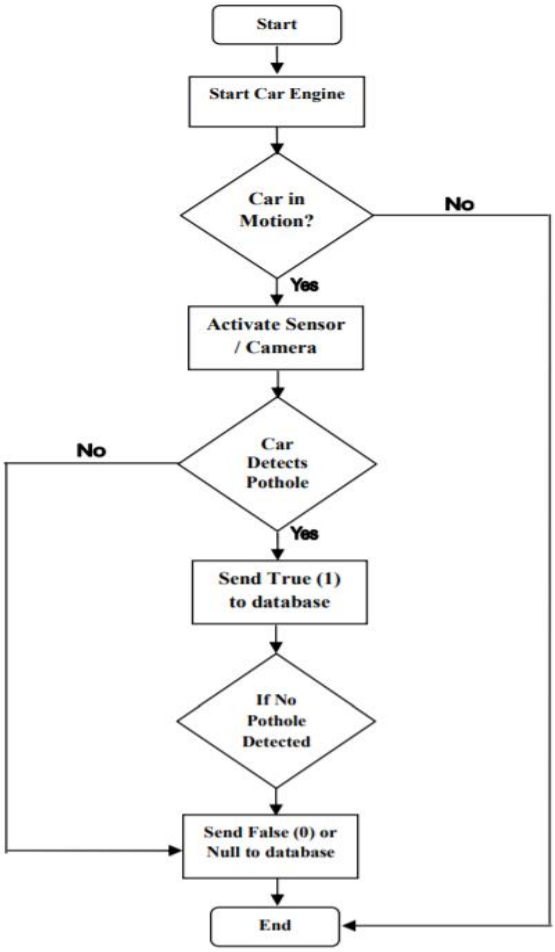
Abstract:

There has been several studies into the detection, reporting and maintenance of potholes. Pavan et al. (2014) explored the use of android smartphones to detect and report potholes. Also Kulkarni et al. (2014) studied the use of machine learning on android to detect and report potholes. Other studies have used RFID, sensors and cameras to detect and report potholes (Sudarshan et al., 2009; Youngtae & Seungki, 2015). Further research works have also studied pothole detection and management using simulated potholes.

Keywords: Pothole Detection, Pothole Reporting, Pothole Management System, Internet of Things/Everything

I. METHODOLOGY

This paper used an open hardware device and a prototype vehicle to build an IoT enabled device to detect, report and manage potholes and road surface obstacles. The paper used an Arduino microcontroller board to build an interactive and context aware system which can sense and control objects in the physical environment. An alarm system and a light emitting diode (LED) were interfaced with the Arduino microcontroller to give signals of the detection of potholes and bad road surface conditions. The study used a light dependent resistor (LDR) controller to sense, detect and report potholes and other road obstacles. Potholes and bad road surface conditions detected were sent via a subscriber identification module (SIM) card for onwards transmission to the server for processing.



Challenges of Internet of Things

i)Connectivity Issues: Network connectivity and integration of devices into various networks for communication is a challenge to internet of things. Heterogeneity of network technologies and low communication speed and bandwidth is a challenge to internet of things (IoT).

ii)Power Issues: Power is one of the challenges of internet of things. Most IoT enabled devices and systems operate wirelessly and are fitted with batteries that last for very few hours.

iii)Context Processing: Another challenge of internet of things is that; some IoT enabled devices are unable to detect and process complex environments

iv)Security Issues: Security is another great challenge of internet of things which seeks to interconnect the world of objects to the virtual world thereby allowing all kinds of objects to communicate and share information.

v)Standards, Policies and Regulations: The lack of standards and policies hampers the fast development of internet of things. Rules and regulations are needed to enhance the development of IoT devices and systems and their implementations.