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Pothole detection for accident prevention: A review

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ABSTRACT

Potholes are a nuisance to society, especially to individuals who use public roads. The importance of roadinfrastructure for the society is comparable to the importance of blood vessels in humans. Potholes and humps are the main factors that cause road accidents and damage tothe vehicles. They should be spotted and corrected beforethey become a hazard. Road conditions can thus beimproved through the detection of potholes. It is the goal ofengineers to continuously monitor and repair the roads toensure that they are in good shape. Having objective andcomprehensive data about the state of the roads is apromising method for achieving this objective. About two million kilometres of roads in India are surfaced and around one million kilometres are poorly constructed. The various problems that plague Indian roads are largely caused by the improper maintenance of the roadways. No matter where you go in India, you'll find one or more roads with potholes. While Indians have learned to perfect their driving skills to compensate for dishevelled roads, there are many accidents around the country. This paper compares various subjects such as YOLO, SSD, HOG, Neural network, Inception V3,2D LiDAR, CNN-DL, R-CNN etc. for predicting well holes. This paper introduces the state of the art in well-known mining detection techniques that discuss a variety of methods and identify the best solutions for real-time implementation under extreme conditions and working conditions thereby ensuring human safety.

Keywords—*Machine Learning, Deep Learning, 2d-LiDAR, NodeMCU, potholes, accidents, R-CNN, YOLO*

1. INTRODUCTION

India, being one of the fastest growing nations recently after China and despite the fact that India's growth in fields like education, digital learning, industrialization, modern technology is remarkable, yet there are certain grey areas where India is lingering behind. Roadways sustaining one ofthe largest modes of transport in most of the countries, which is road transport, acts as one of the most striking fundamental actualities which adds up to the fundamental development of the nation.

A pothole is defined as a bowl-shaped depression in the pavement surface and has a minimum plan dimension of 150mm [8]. In India, potholes are so frequent that as amatter-of-fact we Indians can find potholes at everykilometre and speaking as facts, in a developing country like India deaths happening due to potholes or people getting injured is still not regarded as a major issue. Every year around 3597 people die due to potholes. More than 30% of people die due to potholes. The Ministry of Road Transport and Highway has provided figures that over 9300 deaths, 25000 injured in the last three years and more than 25,000 people are getting injured due to potholes.[21] Despite all these fatalities and injuries, the potholes continue tooriginate and increase in numbers and there is lack of attention towards it.

The occurrence of potholes has increased rapidly due to extreme weather conditions such as heavy rains, extremely hot summers, which has a great influence on traffic safety and road damage. It causes social problems such as vehicle breakage and accidents, which are causing social costs. Therefore, automatic pothole detection methods are being studied for efficient pothole detection and pavement management [13] so that these potholes can be repaired at the earliest and we get away from the damages sourced fromthem. Vehicles tend to lose balance when they come acrossa large pothole. Whenever a driver slows down the vehicle to avoid the pothole, there are chances of collision with the vehicles following it, whose driver has no idea about it. So, information sharing plays a very important role in avoiding the effects of potholes [10].

2. OVERVIEW OF THE EXISTENT POTHOLE DETECTIONMETHODS

Pothole detection being an interesting subject of research, specialists have been taking a shot at various pothole detection methods. Some of the pothole detection methodsare referenced underneath.

A. Development and Analysis of Pothole detection and Alert based on NodeMCU

The safety of vehicles is the first priority when it comes to road construction and maintenance.[7] However, many of theroads in India are in poor condition and have caused accidents. This issue can be solved by monitoring the condition of the roads and by sending a location request to the maintenance authority. In this paper the potholes are detected by using ultrasonic sensor and the location (latitudeand longitude values) are given with the interfacing of GPS module and node MCU. The location is shared with the helpof IFTTT Webhooks which is linked to the maintenance authority's G-mail Id.

The Components used are NodeMCU (esp8266 wi-fi source module), Ultrasonic sensor, GPS module, server database The software mainly consists of two parts, one is controlpart, and the other is triggering part. It is intended to give a general idea of program flow and implementation. Once the Node MCU is connected to a Wi-Fi network, it should be able to receive and send location information. The distance iscalculated between the sensor and the obstacle is measured by the time it takes for the wave to hit the object and reflect back to the sensor. The depth is then calculated by dividing the distance by the vehicle's ground clearance level. The calculation shows the depth of the pothole. If the depth is zero then there is no existence of pothole at that place. if the depth is greater than zero then the GPS Module sends the location of the device to the microcontroller.

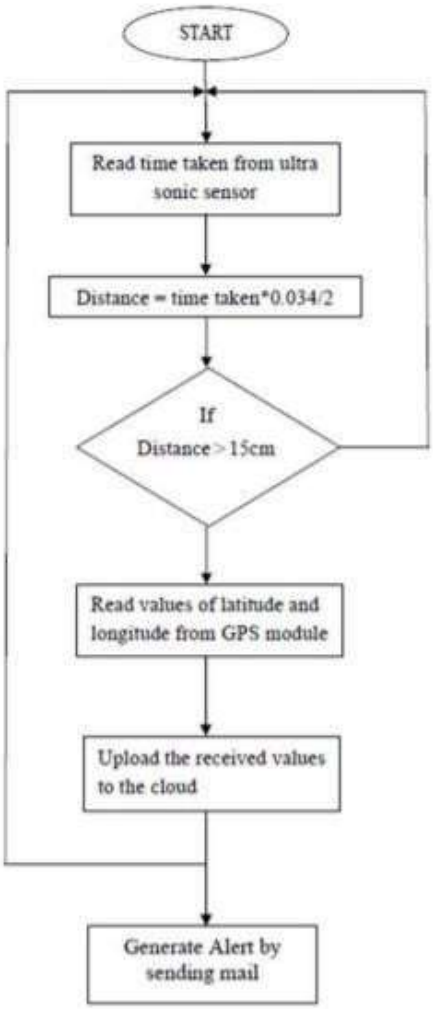


Fig 1a-Flowchart For Pothole Detection Using NodeMCU

The server is responsible for providing the location information to the device. In order to achieve this, the servermust be able to connect to the sever and act as an intermediary platform. In this platform the micro-controller and the G-mail must be integrated to as receive an e-mail. The service that we need to implement is called IFTTT. It isa webhook that will allow us to trigger an event with the server. In this event should be triggered using the micro- controller using the values of latitude, longitude and the depth of the pothole. This whole process is represented with the help of flowchart shown in Fig 1a.

B. A Deep Learning Approach For Street Pothole Detection

Potholes are a big issue on the road surface. They can cause vehicular collisions and damage to the vehicle. This paper proposes an efficient method of detecting potholes that uses machine learning and Artificial Intelligence Algorithmsto detect potholes. The dataset they [2]chose was created by the Electrical and Electronic Department, Stellenbosch University in 2015. The entire dataset consists of two different sets, one was considered to be simple and the other more complex. The dataset is collected by clicking pictures on smart phones by setting it up on the dashboard of a car. They trained and tested various models with pre-processed datasets and came up with a model which is faster R-CNN that is YOLO V3.Using YOLO V3,the training of this model is done in full images as well as possibilities for class in binding boxes. This way it has more advantages than the actual methods of object recognitions.

YOLO is a neural network algorithm that is used to detect objects in images. It works by predicting the vector ofthe objects in the images. It works by separating images intoa grid in SxS size. Every cell in the grid can predict N possible binding boxes and level of probability (e.g., self- confidence points) which is exactly what in our situation a pothole. The YOLO V3 version is quicker compared to many other superior algorithms. A complicated pipeline isn'talways needed due to the fact YOLO V3 works on item detection as a regression trouble.

YOLO V3 unlike other methods like CNN does not classify a background image as an object and thus YOLO V3 uses the whole image instead of just the predictions. So the error rate of YOLO V3 in terms of background errors is half of what it is for the CNN model. It allows the model to have all the details about the objects that are in the image. YOLO V3 learns the object's general structure instead of theexact shape. This feature makes it more accurate in predicting the natural photos.

The YOLO V3 model performed exceptionally well with an accuracy of 82%. The goal is to develop an object that can identify broken drains and manhole covers using images taken from vehicles.

C. Pothole Detection And Warning System: Infrastructure Support and System design

Congestion has become a global issue due to the increasing number of vehicles and the rising population. It has negative effects on the environment and human health. Elements that can cause a driver to behave carelessly are considered the leading causes of vehicle crashes. Being aware of the potential collision can help improve the behaviour of the driver. Vehicle networks are beingdeveloped to provide drivers with vital information about traffic conditions and road conditions and potholes being one of the culprits of faulty road conditions, therefore, the concept of a pothole detection system can be integrated into a vehicle so that it can alarm the driver when there are condemned road. One such project is the Wi-Fi based Pothole Detection and Warning System, which will help the driver avoid potholes.

In this section [11], we propose to design infrastructure enables

mobile nodes (vehicles) to access files for details of road conditions around them. This information will be transferred to mobile nodes in the form of packets, which will distributed by access points.

The entry point will be to stream packets via UDP (userdatagram protocol), will not require any phase to stop the connection. As also when mobile nodes come under the influence of the access point, they can find package. It is possible that the first few packets may be anointing, but you think it's a high packet distribution the rate of access point, the background of the mobile willfind packets successfully.

This information can be used to update the data at theaccess points. It can also be used to remove the false positives.

This method will allow the system to learn from its mistakes as it goes along. It eliminates the need for manual intervention and ensures that the system only needs to be setup once and only once, since it will automatically generate the correct location coordinates for the access points.

The location information that is contained in the packet thatthe access point sends is very useful for a mobile network. Since Wi-Fi is a wireless network, it can transmit data in theair, it has the same properties as a non-switched wiredethernet network therefore it is prone to collisions. Insteadof having a collision detection system, it uses a packetexchange to prevent collisions.

However, research shows that such divine use reduces the outpouring of the system and may be better for the construction of a system where natural settings are known. Therefore, by avoiding the use of RTS / CTS we increase the chances of collisions, and the package is folded, but on the other hand we reduce more and increase the chances that the information package can be accessed in real time.

In other words, it can replace symbols, marking boards and markers, and perhaps much more. The advantage of using this technology is its powerful properties. We can process data stored in access points from connected servers. Using this program design, many programs such as the acquisition of potholes can be distributed over a road-help framework.

The paper describes the challenges of designing a Wi- Fi-based infrastructure that enables vehicle drivers to collectand transmit data related to driving conditions. The system can also detect and warn drivers about road hazards.

D. Pothole Detection System Using 2D liDar andCamera

The Indian traffic scenario is different from other countries in that it has many unique challenges [13]. These include the lack of discipline and the chaotic nature of the lane traffic. Automatic Pothole detection is very important for proper maintenance of asphalt-surfaced pavement. Dueto the increasing occurrence of pothole, the need for automatic detection methods has been studied. These methods can help minimize the cost of repairing and maintaining the road surface. Although vibration-based methods are more accurate than traditional ones, they can provide inaccurate results. Laser scanning systems are also more reliable in detecting potholes. Although vision-based methods are more accurate than 3D laser scanners, they maybe harder to identify a road patch due to the noise. Instead, these methods rely on the light emitted by an object. LiDAR is a type of three-dimensional mapping system thatis used for various fields such as environmental observation,autonomous vehicles, and space facility.For pothole detection, open-source computer vision is used. This library contains many image functions that can be used for various video-based applications. 2D LiDAR and camera-based system is more cost effective and does not require any interference with the road surface. Therefore, in this paper 2d lidar is used than normal liar and 3d camera. This is shown in Fig 4.1

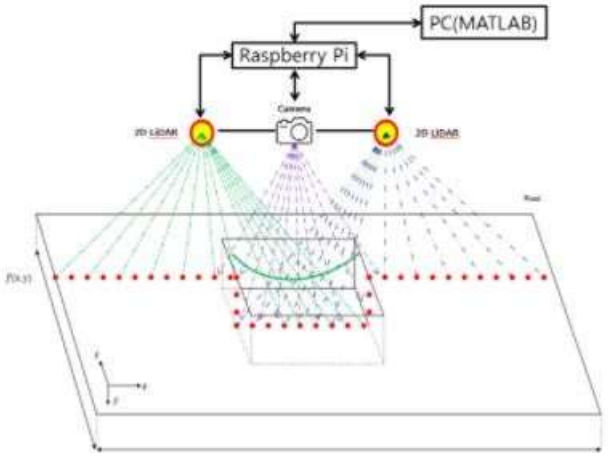


Fig 4.1 - Pothole Detection Using Li

To get an accurate pothole using 2D LiDAR, four steps including filtering, merging, line extraction andgradient for the data functionality is performed. First, filtering applies is done because the collected LiDAR data contains audio distance data. Therefore, noise reduction is used in the middle filter and it is a pre-processing step to improve the discovery of the pits opportunities. For each angle, the median value is the median value after all the entries in the window are sorted by number. Next, LiDAR sensor point cloud data may be combined by finding the distance between two adjacent points and calculating therest area using the appropriate limit number, adaptive breakpoint detector (ABD) it is a way that I can build a connection according to Dmax. The following equation (1) is a reference to finding Dmax. Fig 4.2

$$D_{max} = r_{n-1} \cdot \frac{\sin(\Delta\emptyset)}{\sin(\lambda - \Delta\emptyset)} + 3\sigma_r \qquad (1)$$

Fig 4.2 – Equation To Find Dmax

If it meets the status quo, points pp1 ~ ppnn no treated as a single group [4]. After meeting about point point data, part of the line the background was made. Repeated end point (IEPF) an algorithm is used for partial extraction of the line [2]. Next, the A data activity gradient is created to determinepresence of the mine. In Fig. 3, f (x, y) is a pothole data function behind the line discharge. To determine whether f (x, y) is a pothole or not, first Order separation f (x, y) is performed. If there is a well there, f variance form f (x, y) has a sudden change in the file of function. P (xx1, yy1) firstpoint suddenly changed to the waveform form difference, and P (xxnn, yynn) is the last sudden change point. Where the pothole is, the width and depth of pothole available as Fig 4.3

$$\text{Width} = \sqrt{(x_1 - x_n)^2 + (y_1 - y_n)^2} \qquad (2)$$

$$\text{Depth} = \left| P_{ymax} - P_{ymin} \right| \qquad (3)$$

Fig 4.3 – Equation To Detect Pothole Depth

A porthole detection system that uses an image instead of a laser

scan can improve the accuracy and reduce the cost. Since the data in the black box is exposed to various noises, image noise filtering is performed before the analysis begins. Gaussian blurring algorithm is used to remove the noise. Binarization simplifies the process of classifying a flat object into two groups: the shape and the size. After noise filtering, we get the right shape and size of the object.

We developed a 2D LiDAR and camera-based pothole detection system. By using two LiDAR's, we can detect the width of the road surface more accurately. Then, we developed a filtering algorithm and a line extraction algorithm to improve the system's performance.

E. Pothole Detection System using Machine LearningOn Android

Android and Google's mobile operating system, hasbecome the most widely used platform in the world [15]. Its continuous improvement and robust SDKs make it a great place for aspiring developers to start. These services are different from the old ones. They allow us to consume data collected by sensors without leaving the past. They are also widely used in the modern world. In this paper, we will evaluate a system that uses a neural network to detect the presence of Potholes. The system was developed by us due to its ability to process sensor readings. This section describes our goal to develop a system that will allow users to identify and report potholes. It will also allow the authorities to immediately dispatch the necessary pothole.

The user launches the application, which has the algorithm plug-in running .it detects pothole while user is driving. It then displays the locations of the potholes along the road and its speed. The app also adds a variety of features such as driving statistics, geographical co-ordinates,and maps. When the user completes his/her journey, he/she taps stop presented with the event log. This log will be maintained in the database. The information saved in the database and it will distribute in .csv format. This application can help drivers keep track of the condition ofthe roads they're driving on. It can also inform the local authorities about the road's condition and its locations.

Proposed algorithm is that the low-frequency components from acceleration signal in x-axis and z- axis are removed using high pass filter this is shown in Fig 5.

The z-axis is a prime example of road anomalies that can be detected with the Peak acceleration filter. A real pothole event with a significant z-peak acceleration should result in a significant x-axis peak. This filter rejects windows where the peak z acceleration is less than a factor _ts'times the speed of travel.

1. By using high pass filter

```
final float alpha = (float)0.8;
gravity [0] = alpha * gravity [0] + (1 - alpha) *eventvalues [0];
gravity [1] = alpha * gravity [1] + (1 - alpha) *eventvalues [1];
gravity [2] = alpha * gravity [2] + (1 - alpha) *eventvalues [2];
```

2. High-pass effect: Removing of low-frequencycomponent

```
accelerationValues [0] = eventvalues [0] - gravity [0];
accelerationValues [1] = eventvalues [1] - gravity [1];
accelerationValues [2] = eventvalues [2] - gravity [2];
```

3. z-peak : Assume threshold on z-axis will be tz Reject the reading if Acceleration A neural network is also used in this system to apply Machine Learning on Android and improve the efficiency and accuracy of pothole identification. An Artificial Neural Network (ANN) is a data processing paradigm based on how biological nervous systems, such as the brain, process data. It is made up of a vast number of processing elements that are all strongly interrelated.

Parameters for the Neural Network

1. input layers = 3
2. Input1= acceleration on x-axis
3. Input2 = acceleration on x-axis
4. Input3 = acceleration on x-axis
3. hidden neurons = 6
4. output layers = 1
5. Output1= pothole decision.
6. Activation Function = Sigmoid
7. Neural Network Algorithm = Back propagation

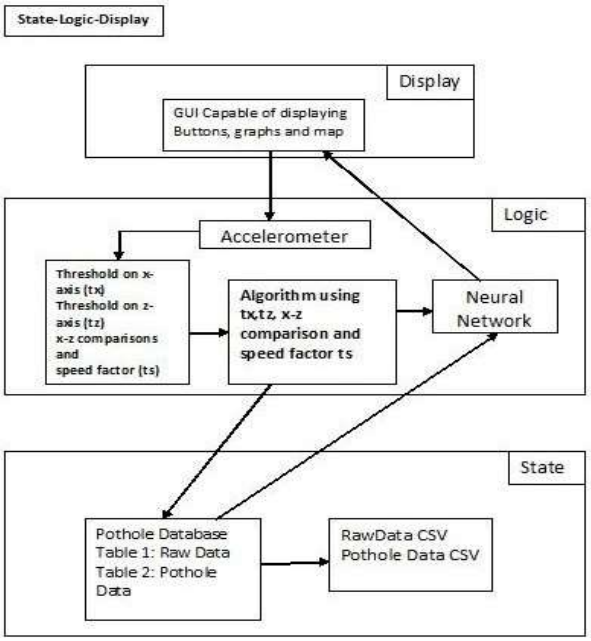


Fig 5- Architectural Pattern For Pothole Detection System

F. Pothole Detection using Machine Learning

In India, about 3,000 people die yearly due to road accidents caused by the lack of basic infrastructure such as potholes. In Britain, the cost of fixing the roads with potholes is estimated at 12 billion Euro. [17] Only 28 countries have laws that address the five main risk factors involved in road accidents: speed, drunk driving, child restraints, and wearing helmets. For the study, the two researchers focused on 14 accident types and introduced various risk factors such as human factors, vehicle and environment factors, to identify the likely cause of an accident. Various sensors are used to identify the location ofthe potholes and humps on the road. A low-cost model was proposed that utilizes the Kinect sensor to provide direct depth measurements. The images are segmented by the terms of partial differential equations. The training model is then used to determine the exact location of the defects. Unfortunately, this method can't detect the defects if the images are not illuminated properly. This paper presents an efficient method to detect road distress using mobile devices.

Every movement should have its own sensor value. In order to get the most out of it, we need to use two sensors:

a gyro graph and an accelerator. Through a smart phone, we can easily collect data on various movements.

Transfer learning and Inception V3 is a widely used machine learning algorithm for classifying general itemsand objects. In

this research, we study how it can be used to identify the objects and items that are already existing in our environment. Transfer Learning is a process that allows us to recognize different concepts in a shorter time frame.

Our approach consists of two steps: acquiring road status information through GPS and acceleration sensors, and processing that data pre-processor for CNN.

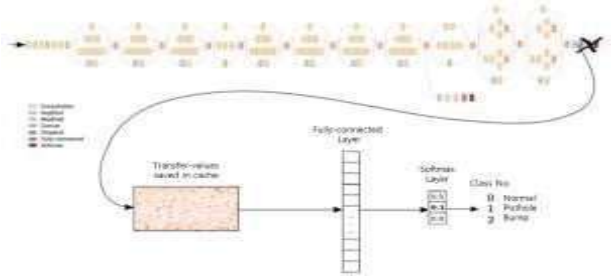


Fig 6.1 – Represents Data Collected By Sensors

Fig 6.1 shows the data collected by sensors when a vehicle passes over a pothole. It shows that the vehicleis passing through a flat path with a low frequency.

We can see high frequency oscillations for a pothole inFig 6.2

Fig 6.2 – High Frequency oscillations For Pothole

G. Realtime Pothole Detection System Using Android Smartphone with Accelerometer

Human reports are very accurate in detecting road damage. However, they require more human interaction and are not comprehensive.[18] Vehicle counting and vibration sensors are commonly integrated into the pavement to collect data. However, this technology is not yet widely used due to its high cost. Participatory sensing could allow users to collect data on various aspects of a community. This method is similar to the concept of participatory photography, where people take photos of road hazards and submit them to a central database. We believe that an automated system that can detect potholes with minimalhuman interaction is more promising.

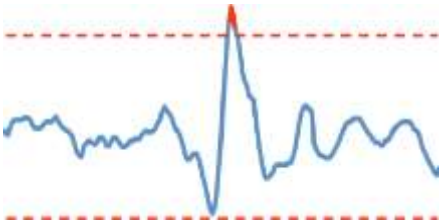
The data collected by the sensors was used to createa road map with various potholes. The device was made to work seamlessly with the Tmote Mini sensor node with Texas instruments microcontroller MSP430F1611 and the analog devices ADXL335 and AD430F1.For raw acceleration data acquisition MansOS based software was used and it is transmitted through USB interface to a laptop.

1. Algorithm Z-Thresh: The algorithm is used for event pothole detection of various data sets. It uses z-peak mode to threshold the acceleration at Z-axis. it measurements are the values exceeding the specific threshold value and identify type of potholes. This algorithm assumes that the Z-axis position of the accelerometer is known. It can also reorient the device by controlling its placement. Fig7.1.

2. Algorithm Z-DIFF: The Z-DIFF algorithm was then tested on the data set. It was able to detect the change in vertical acceleration data by detecting deviations in the readings. The algorithm detected fast changes in vertical acceleration data and it requires thedetermination of the Z-axis position. Fig 7.2
.

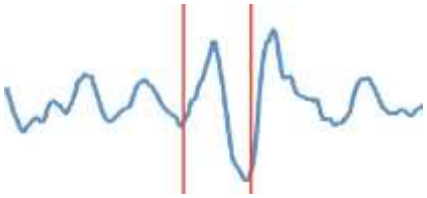
3. Algorithm STDEV(Z): Some of the techniques that were used in the previous work were thenimplemented in post-processing. One of these is the use of a standard deviation of vertical acceleration. The algorithm had to be tuned to take advantage of the various window sizes and threshold levels. Fig 7.3

4. Algorithm G-ZERO: A search for patterns in visual data analysis revealed that there are events that happenin a certain data set that are characterized by a specific measurement tuple. These events could be triggered bya vehicle entering or exiting a certain location. The algorithm G-ZERO was developed to identify the location of potholes. Fig 7.4



Algorithm Z-THRESH - Fig 7.1

Algorithm Z-DIFF - Fig 7.2



Algorithm Z-STDEV(Z) - Fig7.3

Algorithm G-ZERO - Fig 7.4

H. Smart Detection and Reporting Of Potholes via Image-Processing Using Raspberry-pi Microcontroller

The evolution of the field of sensors and electronics has greatly impacted the way we live. [23]This has led to the emergence of various concepts such as Smart Cities. Currently, each vehicle has around 60-100 sensors on board. These sensors allow the vehicle to identify different road distresses andprevent damages caused by them. Potholes are usually caused by the presence of water in the asphalt pavement's soil structure. This contributes to the formation of the cracks.

This topic also discusses the various systems involved in the automatic detection of potholes. The system consists of a module that was attached to the vehicle's camera, which would act as an indicator if thecar was started or if a report was sent. It also has three LEDs that would turn on once the vehicle is inspected. The concept of the system is to use a car's size to determine the position of the camera module and the angle at which it should be placed to detect the potholes. The vehicle's

size also helps in preventing the system from accidentally hitting the road. The camera was mounted in the upper portion of the car to get a good range and to capture images quickly. It was also secure and stable to prevent unauthorized changes in its position. The algorithm was derived from a micro-controller. It is commonly used in real-time applications. The image processing is done in real-timeand can be performed efficiently even in low-end systems. The automatic reporting system is a component of the project that would allow the users to report about potholes. It would be carried out by a Raspberry-Pi equipped with a GPS module and a webserver.

A dedicated computer was then connected to the main server to receive and collect the data from themicrocomputer. The device would then inform the userif the report was sent. After detecting a pothole, the microcomputer sends the coordinates of the location ofthe object to the receiving end. The system then reports the exact location of the pothole. The two interfaces were used for the various components of the system. The first one is for the automatic detection scheme while the second one is for the pothole reporting system. The interface only contained an LED to tell the driver if a pothole was detected. The data collected was then sent to a server that would be used to report the details.

The performance of the system is calculated using the following formula. The results are presented in Table given below Fig.8:

Parameter	Ideal Set-Up	Non-Ideal Set-Up	Ave
Accuracy (Detection)	100%	87.45%	93.72%
Sensitivity (Detection)	100%	93.22%	96.61%
Specificity (Detection)	100%	85.71%	92.85%
Success Rate (Reporting)	100%	100.00%	100.00%

Fig .8

THE TABLE 9 REPRESENT THE COMPARISON TABLE BETWEEN THE METHODS OF DETECTIONS OF POTHOLES ON BASIS OF ADVANTAGES AND LIMITATIONS AND ACCURACY

VEHICULAR AUTOMATION RESEARCH				
PAPER TITLE	AUTHORS	TECHNOLOGY / SOFTWARE / TOOLS USED	ADVANTAGES	LIMITATIONS
Development And Analysis Of Pothole Detection and alert based on NodeMCU	M. Bharath Chandra Balaji Santanu Kumar Dash, K. Aruna Kumari	Node MCU, GSM Module, Ultrasonic Sensor Arduino Programming and distance calculation is done and then computed and finally mail is sent to the respective address	-Basic Components are used, therefore it is easily available. -It is a cost effective method to tackle the potholes by sending the location to the respective authorities. -Effective automatic detection of potholes using depth based analysis.	The Vehicle will run over the pothole and there are chances of accident taking place. But in this system there no sytem to avoid the collision. Copious amount data should be managed so it would hav been if a management system was also designed. During Rainly season results may not be accurate due to water accumulation.
A Deep Learning Approach for Street Pothole Detection	Ping Ping, Xiaohui Yang, Zeyu Gao	Deep learning Algorithms which detect pothole on roads Image Processing YOLO (You Look only Once) Algorithm SSD (Single Shot detector) HOG (Histogram Of Oriented Gradients) with vector support	-Yolo is the fastest among deep learning tech. -Yolo is pretty fast and decent in terms of object size also. -It can detect potholes automatically using available data.	-Deep learning techniques sometimes use complex algorithms that slows down the processing speed. -It detects potholes but takes a lot of time to process all the image data sets. -On comparision with YOLO is 82% accurate but there are better methods which provide more accurate results.
Pothole Detection and Warning System: Infrastructure Support and System Design	Sudarshan S Rode, Shanil Vijay, Prakhar Goyal, Purushottam Kulkarni, Kavi Arya	A novel Wi-F based infrastructure enabling application data transfer to the vehicles moving on the roads.	Assist the driver in making strategic and real-time tactical decisions in varied environments by ensuring that the driver gets information about potholes well in advance and has sufficient time to take decision according to the prevailing road conditions.	It Mainly Doesnt detect potholes completely as it requires a huge data set which has to be updated frequently. And the main thing is that it doesn't have information regarding the construction on roads, locations and traffic congestions.
Pothole Detection System using 2D LIDAR and Camera	Byeong-ha Kang and Su-il Choi	2D LIDAR and Camera	-2D LIDAR and Camera based pothole detection system has the advantage that is not affected by the electromagnetic wave and the road surface state. -It is a cost effective solution. - Wide area of the road surface can be scanned more accurately. - Pothole detection using video data is combined with that of 2D LIDAR, and combined data gives more accurate pothole detection performance.	It becomes difficult to recognize pothole due to noise such as shadow, road surface patch, etc.
Pothole Detection System using Machine Learning on Android	Aniket Kulkarni, Nitish Mhalgi, Sagar Gumaste, Dr. Nupur Giri	Neural network has been implemented using a machine learning Accelerometer and GPS	-There are various files generated after the data collected and processed. These include PotholeData.csv, FilteredPotholeData.csv, and NeuralNet. -The neural network achieves its error rate by performing thousands of iterations. It shows that its accuracy is over 95%. -The permissions were matched to the appropriate sensors and to the conditions of the data col The result is computed in real time and sent to an e- mail address. The system can then be used to inform the appropriate authorities if needed. -The Android device can perform native communication tasks without any problems. Its neural network evaluation is the most resource intensive part of the system. -Neural network took only 5 seconds for the neural network to evaluate about a hundred values. This is highly satisfactory considering the objective of the pothole detection system	A. Human Error :- First of all, we admit, that a human operator pressing a button during the test drive is subject to multiple errors due to both technical limitations and human factors. B. Network Provide accuracy :- Network providers location is not always accurate because it is based on cell-site triangulation. This provider determines location based on availability of cell tower and Wi-F access points. Results are retrieved by means of a network look-up. The accuracy depends on number of base stations around you and the quality of the signal. C. Centralized Databases :- As of now, this system is limited to data collected by individual devices. Eventually, a centralized database can be made for users to access all the pothole data across their surroundings.
Pothole Detection using Machine Learning	Hyunwoo Song, Kihoon Baek and Yunghee Byun	Pothole detection, Transfer Learning, Inception V3	The knowledge acquired in Inception V3 to recognize common objects around us can be transferred to recognize a totally different signal patterns.	Transfer Learning depends on the variety of data which might change according to sort of vehicles, the shape of bump and pothole, and etc. Many types and shapes may lead to difficulty in Transfer learning.
Pothole Detection System Using a Black-box Camera	Youngae Jo and Seungki Ryu	Pothole-detection system using a black-box camera , Unique pothole-detection algorithm	The proposed algorithms can correctly remove various types of similar objects, such as patches, manholes, shade, and moving vehicles. By doing so, pothole regions can be detected correctly. The overall sensitivity and precision reached 71% and 88%, respectively.	The processed system failed to detect potholes that were especially bright due to sunlight or due to static water or flat hole. Evaluation is needed under various weather conditions in future research.
Detection and Counting of Pothole using Image Processing Techniques	Vigneshwar K, Hema Kumar B	Image processing and Image segmentation technique	The K-Means clustering based segmentation was preferred for its fastest computing time and edge detection based segmentation is preferred for pothole detection	For multiple pothole detection edge segmentation was better than k-means clustering. If we upgrade edge segmentation and fuzy c-means clustering method we can get the output with high accuracy the only advantage of k-means clustering is to identify the pothole and reduce the computing time.
Real Time Pothole Detection using Android Smartphones with Accelerometer	Aris Madhavi*, Girts Strazdins† Reinholds Zviedris†, Georgijs Kanonirs†, Leo Selavo*†	Mobile sensing, Participatory sensing, accelerometers, Pothole detection algorithm Z-THRESH, Z-DIFF, STDEV, ZG, G-ZERO	The evaluation tests resulted in optimal setup for each selected algorithm and the performance analysis in context of different road irregularity classes show true positive rates as high as 90%.	The smartphone Accelerometer sensitivity may not detect the potholes if the vehicles turning is too slow it would, beame difficult for the sensor to find notable fluctuations in acceleration.
A Comparision Of Low Cost Monocular Vision Techniques for pothole distances estimation	S Nienaber, R S Kroon, M J Booysen	Monocular Vision Using A pinhole cam model Camera calibration is done using matrix and determinants and basic formulas of focal length and depth used cross ratio approach	-We can determine pothole in distance of 5-30 m -It can exactly measure the depth of pothole, using pinhole cam and formulas requirement on camera calibration -Using cross ratio approach we can find the exact depth and distance of the pothole.	Pinhole camera needs camera caliberation to be done frequently everytime. Caliberation error take place. The relevant information for applying geometric technique is not available.
A Modern pothole detection technique using deep learning	Abhishek Kumar, Chakrapani Dhruba Jyoti Kalita, Vibhav Prakash Singh	Model Based Transfer learning Faster region based convolution neural network (F-RCNN) ,using accelerometer (without image)	-The camera mounted on the car give a clear picture. -The technique is more efficient and better than other techniques and produces better results.	Its purely a basic system. GSM and GPS could hav been used. This is purely driver based. If pothole is detected the system wont be able to take any action. Its the wholesome responsibility of the driver as it has alerted him and he should be capable of handling it.
DeepBus: machine Learning Based real time pothole detection system for small transportation using IOT	Vaishali Bansal, Kashish Mittal, Gautam Ahuja Ashima Singh, Sukhpal Singh Gill	Machine learing based detection of pothole and IOT and some expressions and algorithms related to detection	-Here we can control the speed of the car automatically when the pothole is detected. -The new technique is introduced named deepbus to get accurate locations of the potholes. -The data will be available through real time map to enable smart transportation.	It cant differentiate the size of pothole, ie the reduced speed is same for small and large potholes. Machine learning requires large data set and acquiring that huge amount of set and updating them regularly is a hassle. Wastesofication is not reduced in this system.

Detection of humps , potholes and Distance between 2 car using ultrasonic sensor and accelerometer	Patil Pallavi S , Khan Abdul A , Saraf Priyanka S Rahmniya Shaikh	Accelerometer, Ultrasonic Sensor, LCD, GSM, GPS, Buzzer	-The proposed system will detect the potholes and humps on the road and save the information in the server. -The potholes are detected and its height, depth, size are measured using ultrasonic sensors and accelerometer -The GPS is used to find the location of pothole. All the information is saved in the database. -This timely information helps recover the road as fast as possible. Also this system measures the distance between two vehicles to avoid road accidents.	Once the pothole or hump is detected only the rider is alerted. If some action such as reducing the speed is done accident can be prevented by a huge number and can save lives. If incase instead of potholes there other obstacles which appear suddenly such as animals etc this method is not efficient enough to handle the situation.
Crowdsourcing Undersampled Vehicular Sensor Data for Pothole Detection	Andrew Fox, B.V.K. Vijaya Kumar, Jinchu Chen, Fan Bai	Vehicle Binary Detection to Cloud Binary Detection, Vehicle Raw Data to Cloud Binary Detection Binary Voting Detection, Idealized Crowdsourced Detection , Filtered Multi-stage Detection	-Crowd sourced data from multiple vehicles can be used to increase the pothole detection accuracy in a generic framework, when using low-frequency embedded accelerometers operating asynchronously and with heterogeneous vehicle behavior. -The tradeoff between the number of vehicles participating in crowdsourcing and detection accuracy is examined, while analyzing how vehicle sensor restrictions and bandwidth constraints affect event detection.Further a detection system to handle these constraints is presented. -The pothole detection methods developed using simulated data can be applied successfully to real-world data is shown.	We have to mainly address the issue of lack of extensive model training data by demonstrating that a detection model applicable to real-world systems can be derived using simulated data. The amount of data present has to be checked regularly and has to be updated frequently and its not simple to analyze so much data as it is a tedious process
Deep Learning Based Pothole Detection and Reporting System	Ganesh Babu R,Challaswamy C Surya Bhusai Rao M,Saravanan M Kandrana B,Shalini J.	Highway pothole detection and information system are proposed based on the CNN-2L algorithm.	-The CNN-2L performs better than the two other benchmark methods -The proposed CNN-2L efficiently detects the pothole at all levels -Accurately identifies the hump and pothole with location information.	A Convolutional neural network is significantly slower due to an operation such as maxpool. A ConvNet requires a large Dataset to process and train the neural network.
Image-Based Pothole Detection System for ITS Service and Road Management System	Seung-Ki Ryu,1 Taeryeong Kim,1 and Young-Rok Kim2	Using various features in 2D images is proposed for improving the existing pothole detection method	-It is cost-effective as compared with industrial cameras and lasers -Used not only in determining the preliminary maintenance of road management system and in taking immediate action for their repair and maintenance, but also in providing alert information of potholes to drivers as one of ITS services.	-Potholes may be falsely detected according to the type of shadow and various shapes of potholes. -further work for improving image processing time and performance of the proposed method is necessary for the pothole detection system to be applied to real-time pothole detection and real pothole alert service.
Analysis and Improvements on Current Pothole Detection Techniques	Sumit Srivastava, Ayush Sharma, Harsh Bakol	Pothole Detection algorithm, cloud, IoT, Ultrasonic, Vibration based detection Vision Based Detection, 3D Reconstruction	-Sufficient to estimate the road quality and avoiding traffic congestion and collisions.	The major drawback was the use of costly equipment, vision cannot be captured from a vehicle moving at high speeds and the computation time that is required for model training and one more setback because of these vibration based methods was getting wrong results and not able to distinguish between a pothole, a speed breaker or a manhole.
Pothole Detection in Asphalt Pavement Images	Christian Koziria * and Ioannis Brilakis	A MATLAB prototype trained and tested on 120 pavement images.	-Automates the process of pothole detection in visual pavement data -The proposed method can successfully detect potholes with an overall accuracy of 86% involving 82% precision and 88% recall.	MATLAB codes sometimes are tedious to make and there are better algorithms such as YOLO. R-FCN that can be used to make it more efficient and accurate.
Gap Trap: A Pothole Detection and Reporting System Utilizing Mobile Devices	Steven Burgert , Dr. Nick Rousopoulos	Gap Trap, Client Device, Pothole Detector, Street Bump, Pothole Patrol, Waze	Gap Trap addresses the issue by automatically discovering and reporting potholes so that motorists may avoid them, and cities may quickly repair them. .	There are many areas where this system can be improved. For example, properly profiling potholes would be a large improvement. Right now the system only uses a g-force threshold to trigger pothole detection, but by testing the system with actual data gathered from vehicles driving over potholes we could properly profile the data using machine learning algorithms. To augment the client device, a navigation-like interface could be implemented. With this feature a user would be warned when a pothole is approaching on the road on which they are travelling and they could take the necessary precautions to avoid it. Another area of improvement is refined search queries. Currently, the searching of the pothole data is not very intuitive or complex. It could be expanded to handle geographic queries and fine-tuned queries
Detection and avoidance of simulated potholes in autonomous vehicle navigation in unstructured environment	Jagannath Karuppasamy, Vishnuvardhanraj Selvaraj, Meiyappa Murugappa Ganesh, Ernest L Hall	Computer Vision, Mobile Robot, Blob Analysis, Pothole detection, Neuro Fuzzy Logic Controller	-Extracting the information from the software also becomes easier as it requires the creation of a single object of the PotResult class, and this object indicates the presence of a pothole and its location. -As the solution for the detection of simulated potholes was developed with seamless integration in mind, it now becomes easy to integrate it with the other subsystems.	Creating blobs/os is highly time consuming due to the file size of BLOBs. BLOBs are inefficient due to the amount of disk space required and access time. Not all databases permit the use of BLOBs.
Smart Detection and Reporting of Potholes via Image-Processing using Raspberry-Pi Microcontroller	Mae M. Garcilianosa, Jan Miles L. Pacheco, Rowie E. Reyes, Jurelle Joy P. San Juan	Image Processing using Raspberry Pi Microcontroller, Cloud storage , Web Server	1.Many of the image capture systems encountered non-ideal set-up errors. These issues were usually caused by factors that affected the quality of the images. For instance, vehicles on the road and other road users could have caused the false perception of certain objects. The success rate of sending reports about detected potholes was 100%. 2. The systems produced average accuracy, sensitivity, specificity, and overall performance. The results of the tests indicated that the systems were very accurate and reliable. The average specificity of the system was also lower compared to the other parameters. It performed better in identifying normal conditions and instances with no potholes.	The RPI3B+ has relatively slow processing speeds and has little RAM. This is overcome by allowing the processor to complete the task. If the processor gets tired, it will start using swap. This will consume more time as it consumes more RAM than normal.

Table 9 - ***Comparison table between the methods of Detections of potholes***

3. CONCLUSION AND RECOMMENDATIONS

In India, it is very difficult for the government to monitor the road conditions regularly enough to prevent the formation of small potholes, which can cause fatal accidents. This study proposes pothole detection methods which are based on Node MCU,2D LiDAR and Camera, Image processing, deep learning algorithm machine learning image processing neural network transfer learning and manymore techniques.

More practical calibrated results will be obtained and examined to implement the proposed methods everywhere in the future. The important detail of our project is assisting in repairing and maintaining the roads, thus using thesesystems with high level technologies and ideas for the increased development of roads and prevention from accidents, we can guide cities towards its development, hence turning them into smart cities leading to the safety of human life.

The above given methods are analysed and the required results are obtained but then there is always scope for improvement as potholes cause damage to vehicles as wellas us humans only detection is not sufficient, necessary actions should be taken so that collisions can be controlled and we can ensure a safe travel.

The actions can be either controlling the speed of the vehicleor using artificial intelligence systems which act according to the

situation or even it can be to the extent of avoiding it by changing lanes or going through it at lower speeds so thatthere would be no damage caused.

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