

Automated Sensor based Pothole Detection System for Preventing Unfortunate Causality

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Abstract—Roadways have gained immense popularity and preference worldwide among other means of transportation. Orderly and well maintained roads provide vital contribution to economic growth. They pervade areas and helps to simulate economic and social development. In developing countries like India, maintenance of roads is an emerging concern as it creates disturbances to smooth travel and cause damage to vehicles. The key to monitor road conditions is by detecting road irregularities including potholes, humps, roughness levels etc. These irregularities have major impact on traffic safety and driving comfort to passengers. This study proposes a cost effective and power efficient solution for pothole detection. Here, a vision based approach is utilized to form an advanced piezoelectric sensor system in an unstructured habitat with the aim to perfect road surface, discover potholes and predict their extremity. Further, GPS determines the area of the potholes at local server.

Index Terms—Road irregularities, Pothole detection, piezoelectric sensors, GPS, safety, sensor based approach

I. INTRODUCTION

India has massive road network across the world. In fact, major percentage of India's entire rider traffic employ roadway system to mitigate. This passage has surged moderately over the years with the advancement in all corners of the country. With the growing demand it becomes extremely important to verify quality of roadways. Road irregularities should be observed regularly and repaired essentially. Traffic congestion is expanding popularly in metropolitan cities and has been growing extensively as a ramification of expanding computerization and urbanization. It is an inescapable condition and thus gives an inherent result on how society operates. This blockage reduces utilization of the moving infrastructure, increases time period and most significantly, causes traffic mishap.

The framework of complex roadway network in the developing countries needs prompt attentiveness. Road accidents have been a serious concern lately. According to the report by the Auto mobile Association, Potholes are the leading cause of unfortunate calamities. Motor Vehicles tend to mislay balance while moving across a large pothole. The Potholes are common type of distresses on asphalt pavements resembling like a small, bowl-shaped depressions in the pavement surface [1]. Literature has revealed that asphalt pavements are the primary constituent of road transportation network, and their grade

might drop mainly due to ageing and deterioration of surface [2]. A general depiction of the potholes in an unstructured environment has been indicated in Fig 1 [3]. The pothole mending is requisite in circumstances where they trade off welfare and walkway ride-ability. These irregularities are the outcome of weather states including water residing in the road cracks, temperature variation or on account of weight of hefty motor vehicles.

These irregularities cause road disruption leads to severe consequences and are mainly due to environmental degradation like rain, soil erosion, and poor drainage systems and so on [4]. Potential source of pothole formation is due to collection of moisture in tiny pit and splits on irregular surface. As the temperature varies, this moisture frost and defrost leading to weakening the roadway and cracks in pavement [5]. There are cases when driver choose to slow down the speed of vehicle so as to avoid the effects of pothole and the chances of collision with the other vehicles.

Hence, information exchange plays an important role in avoiding the effects of potholes. The hindrance in the maintenance of these effected roads results in severe damage to property and congestion on roads.

As per the World health organization (WHO), auto mobile collisions leads to more than million death worldwide leaving a negative impact on health and well being of survivors. In order to reduce the count of lost lives, an insight for interventional driving strategies and preventive measures are required to reduce risks of accidents on roads. Furthermore there are innumerable factors that affect the number of road accidents globally [6]. Fig.2. shows the rough estimation of contribution of assorted factors such as drunken driving, over speeding, road irregularities etc. to auto mobile fatalities. While numerous facets contribute to vehicle causalities, motorist behaviour is prime origin of 45 percent of unfortunate calamities. Drunk driving and over speeding are too prominent to fatalities [7]. This indicates the condition of on maintenance of roads.

Potholes are highly liable for automobile accidents. These calamities can be avoided and improved by either alerting the driver driving the vehicle about the likely crash or by managing the automobile on its own.

Consequently, the ceaseless inspection and computation of

urbane framework is decisive for security, accountability and ride-ability. Currently, the physical vision perusal at periodic intervals is the ruling form of situation assessment. Thus this problem needs an immediate contemplation.

For this purpose we have highlighted an idea to detect potholes on asphalt pavements with the help of an advanced piezoelectric sensor system in an unstructured habitat with the aim to supervise road surface, recognize potholes and predict their sternness. The idea is to establish an automated process, which could help in preventing unfortunate casualty due to potholes. This paper briefly reviews the existing approaches and proposes novel framework of pothole detection using sensor which is cost effective and highly portable.

Different approaches of basic pothole detection have been studied and analyzed across the world. We will discuss diverse methods and algorithm researched and performed by various researchers for resolving the issues and damages due to road irregularity in subsequent section of this paper. With increasing research and awareness, detection of potholes will be done with the help of computer aided systems and electrical circuitry in the future.



Fig. 1. Image description of potholes in an unstructured environment

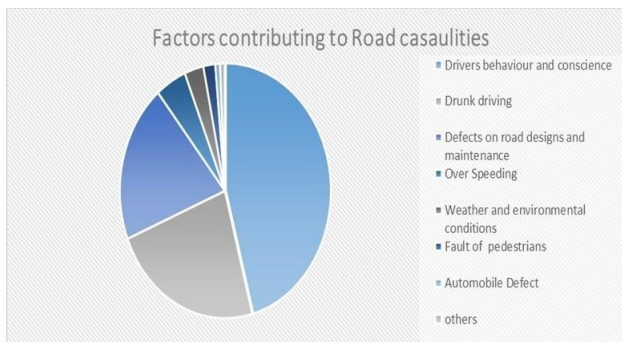


Fig. 2. Factors contributing to road casualties

II. LITERATURE REVIEW

Pothole is one of the threats to road safety. They are hazardous and can damage our vehicle to a great extent. It therefore becomes vital for government-authorities to play with growing-technology to avoid accidents and possibly work on road maintenance.

Pothole detection is a fascinating area of research and various

researchers inscribe the issue of pothole detection in the last few years. Much attention has been drawn by researchers to focus on detection of potholes on paved and unpaved roads. Many of the works have been performed to cater pothole detection.

This section covers brief discussion on various algorithms used by researchers for pavement pothole detection.

A. Mednis and G. Strazdins proposed a model on Real time pothole detection using android smartphones with accelerometer [8]. This vibration based approach utilizes accelerometer for detection and a smart mobile phone application which was developed for processing the sensors output. This results in the output based on the vibration and is highly unreliable on bridge expansion joints due to surface vibrations. Moreover, they gave an incorrect reading if the phone drops. This models was ineffective when it comes to speed breakers, as the android misinterprets the reading of the accelerometer as a pothole. Chang, K. T., Chang, J. R developed a model on detection of pavement distresses using 3D laser scanning technology [9]. In this laser scan approach, the system used an LED linear light, whose rays fell vertically on the road surface, and the 3D projection transform for image analysis. This approach came with promising results, however it involved high calculation time and employ costly equipment's.

W Angorro and A Nasution proposed a model on Design of pothole detection system based on digital image correlation using Kinect sensor [10]. This complex system utilized a Kinect sensor and a camera. The Kinect sensor comprised of two lenses used for depth measurements to give accurate readings. The overall system was highly complex and costly. It only provided 57 degree horizontal view. Hence an array of Kinect was required which was practically impossible to achieve.

D.R. Huston introduced a model on Damage Detection in Roadways with Ground Penetrating Radar [11]. According to this approach radar technology was used for damage detection. The infrared, radar and ultrasonic sensors were placed under moving vehicles or stationary poles that continuously assesses the distance travelled by the reflected wave to calculate the depth. But it was associated with various drawbacks. If they were connected to poles then there was a huge requirement of power. It needed high rigidity and strength to be paved under the moving vehicle. The horizontal range of cut sensors was limited. Moreover the whole system had high complexity and high installation cost. The effectiveness of this method was also prone to bad weather.

Jin Lin and Yayu Liu, proposed model on Potholes Detection Based on SVM in the Pavement Distress Image [12]. The Algorithm was proposed to recognize the potholes of the pavement. In this approach a texture measure based on the histogram was extracted as the features of the image region, and the non-linear support vector machine was built to identify whether a target region is a pothole. It resulted in achieving a high recognition rate. Ch. Koch and I. K. Brilakis proposed a pothole detection model on Improving Pothole Recognition through Vision

Tracking for Automated Pavement Assessment [13]. It was based on histogram texture measure using image processing. In this approach, cameras were used for detecting the potholes with the help of image processing algorithms.

Z. Zhang and X. Ai developed an efficient algorithm for pothole detection using stereo vision [14]. In this surface fitting algorithm was used to estimate the road plane in the disparity map and applied thresholding for detection.

E buza worked on a vision based approach Pothole Detection with Image Processing and Spectral Clustering [15]. In this, the image segmentation was first generated using a histogram based thresholding method and pothole detection was based on spectral clustering. This was done using the texture comparison of the areas inside and outside the pothole. Also the images have to be processed further to obtain useful data from them. Even though image processing provides promising results, there were many short comings for this methodology. Image processing algorithms give inaccurate results when it comes to identify pothole near shadow. Moreover a pothole filled with water may not be recognized by the system as a pothole. Irrespective of such algorithms, the main issue that remains with vision-based pothole detection systems is that they require high computational power and memory. And for countries like India with heavy road networks, an enormous quantity of cameras will be required which automatically increases the cost of production.

Pertinent of automated system has lead us to propose work on Automated Sensor based Pothole Detection System for preventing unfortunate causality. Significantly, the idea is proposed to abolish the upsurge of roads accidents caused by growing road irregularities.

To overcome the literature of existing teachings [16], [17], [18], [19], an efficient and effective advanced sensor system has been proposed that uses piezoelectric sensors to detect pothole in the pavement by notifying changes in its voltage corresponding to the applied pressure. These values would help to witness the intensity of the potholes. Further, GPS determines the area of the potholes at local server. Broadly, the readings of these piezoelectric sensors will be fed to a high-speed processor which will determine whether a pothole has been encountered. In fact, these sensors helps the system to distinguish a pothole from a speed breaker. Moreover this piezoelectric sensors require no external power source.

Using this data, damaged area can be prioritized and damage control can be enhanced.

Thus, the overall system complexity and cost is reduced which makes this approach viable. The aim to develop a low response time, low maintenance and deployment cost solution to the problem of potholes.

III. PROPOSED ALGORITHM

This section presents a detailed discussion on the proposed methodology of Automated Sensor based Pothole Detection System for preventing unfortunate causality. The paper aims to propose a relatively simple yet efficient

and economical method to combat the problem of potholes effectively. This advanced sensor system employ a pair of piezoelectric sensors and a high speed processor with basic electronic circuit elements to achieve the same. For real time application, the two piezoelectric sensors are connected to the shock absorbers of the front wheels of the vehicle. Due to their lattice structure, they exhibit unique property of producing a voltage proportional to the force applied to them. Upon encountering a road anomaly, this sudden variation in voltage due to excessive force applied to the sensor is utilized to detect a pothole. As the vehicle advances into the anomaly, the spring of the shock absorber compresses which puts force onto the sensor, which in turn changes the voltage reading across the corresponding piezoelectric sensor.

A dedicated logic circuit continuously monitors the voltage readings of both the piezoelectric sensors and senses the abrupt voltage variation resultant from the traversal over the road anomaly. These voltage readings are used by a high speed processor to determine whether encountered anomaly is a speed breaker or a pothole. This processor further compares this voltage value to a threshold value (V_T) which has been pre-set during sensor calibration. If the reading(s) exceed the threshold, either a pothole or a speed breaker has been encountered. The ambiguity between a speed breaker and pothole is cleared by the fact that speed breakers is usually faced by both front wheels of an automobile and potholes are more likely faced by only one wheel of the vehicle. Hence, the placement of a piezoelectric sensor on each of the front wheels clears this ambiguity. If the voltage variations in both the sensors are above the threshold that is, if both the shock absorbers are experiencing compression then the anomaly encountered is a speed breaker. However, if the voltage variations in one of the sensors is above the threshold, then the anomaly encountered is a pothole. The voltage reading of the piezoelectric sensor attached to the left front wheel of the car is denoted by V_L and the voltage reading of the piezoelectric sensor attached to the right front wheel of the car is denoted by V_R . For our proposed study we have used a toy car that resemble the automated vehicle and springs works as shock absorbers. The Algorithm proposed by this paper has been summarized in the flowchart (Fig. 3.) below.

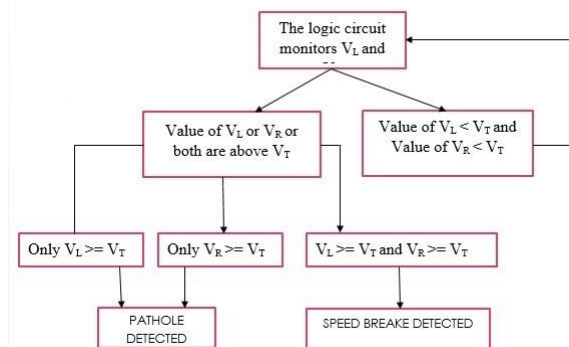


Fig. 3. Flow chart showing the proposed algorithm

Further, GPS encounter the place of the potholes at the local server. Using the data obtained, a more damaged area can be prioritized and damage control can be enhanced The Fig. 4. outlines workflow of our highly portable automated pothole detector.

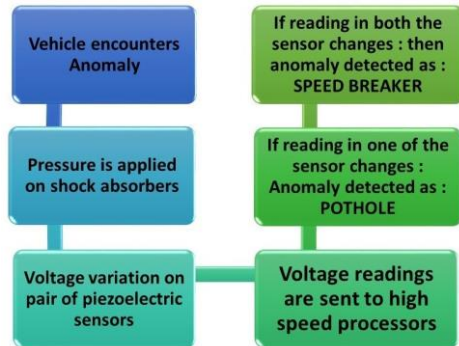


Fig. 4. Workflow of pothole detection using piezoelectric sensors

IV. EXPERIMENTAL RESULT AND ANALYSIS

This active model of the presented system was assessed in artificial environment with unnatural potholes and humps. The readings were recorded by placing two piezoelectric systems on the spring based shock absorbers of a toy car. When the toy car went across a pothole, the spring based shock absorbers would undergo compression thus producing pressure across the sensor and hence producing voltage across it. The threshold voltage V_T is measured as the normal pressure that falls on the piezoelectric sensors due to the weight of the car that is divided equally across both the sensors and is observed to be 0.4V.

Fig.5. illustrates the dimensions of the pothole taken into account. Numerically, they are 70 mm in width and 50 mm in height.

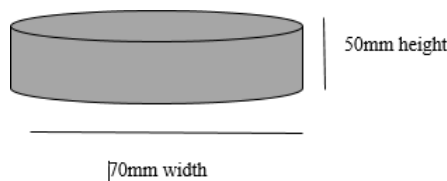


Fig. 5. Pothole dimensions of proposed system

Prior research generally describes that voltage produced to change the pressure across the piezoelectric sensor is given by the piezoelectric constant denoted by d . the piezoelectric constant, d is given in equation (1) and is defined by the ratio of strain development to the applied electric field [20].

$$d = \frac{\text{Strain development}}{\text{Applied electric field}} \quad (1)$$

TABLE I
 OBSERVATIONS OF THE EXPERIMENT PERFORMED IN SIMULATED TEST ENVIRONMENT.

S.no.	Height(mm)	Voltage(V)
1	10	1.5
2	20	2.35
3	25	3
4	40	5
5	50	7

the voltage variation values. TABLE I gives the simulated results of the performed experiment. Consequently, the values of voltage in volts with increasing height of the pothole were recorded.

The Fig.6. hereby illustrates the analysis of line graph of voltage variation versus height of pothole and has been plotted with reference to TABLE I above. Height in mm is marked on the X axis and voltages in volts are marked on the Y axis. While working in the control environment, it was found that the system worked as expected to identify potholes. As the depth of pothole increases from 10mm to 50mm, the voltage variation observed in the piezoelectric sensor increased to 2.7 volts respectively.

The result of this implementation shows that the height of pothole is directly proportional to the voltage variation. Hence, there is a linear relationship between the depth of pothole and voltage observed in piezoelectric sensor of the system. Thus, the proposed system utilizes the piezoelectric sensor to detect the voltage fluctuations and then ultimately fed out the resulting depth of the pothole in the artificial environment.

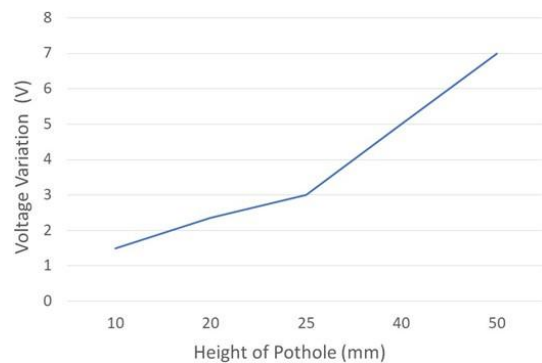


Fig. 6. Line graph of voltage variation vs height of potholes

V. CONCLUSION

Increase in the number of road mishaps is a concern for road safety, one of the main reason is Potholes. Maintaining road safety along with the current expansion rate of road network

becomes a difficult task. The system proposed in this paper is a quick and profoundly tied down framework which gives As the height of the pothole increases from the circumference of the pothole centre, we carried out calculations to find out contactless correspondence and works with observable path-ways. The algorithm introduced in this paper detects potholes using two piezoelectric sensors attached to shock absorbers on front wheel. On detecting the anomaly, it stores the geo location on local server database. Thus this paper provides a realistic, efficient and economical solution to problem of pothole fatalities. Hence it has huge potential for big scale implementation which in turn will increase the road safety by a huge margin.

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