A Collective Study on Methods and Technologies Used for Road Surface Monitoring

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Abstract: Recognizing the condition of the road surface is an important factor for road infrastructure maintenance. It is also important for those who traverse through the roads. Since, it can be used to determine not only an efficient but also a safe path. This in turn ensures least discomfort and damage to the road users and the vehicle respectively. Organizations that are in charge of maintaining road surface conditions highly rely on manual methods. But these manual methods are time consuming and the data collected from this method quickly turns outdated due to constant changes in the road condition. Therefore, using automated methods would be more economical and precise. Several such methods have been proposed towards addressing this problem through the years. This paper analyses various such road condition detection systems and the technologies used in these methods.

Keywords: GPS, Potholes, Navigation, Infrastructure Maintenance, Road Surface Monitoring.

I. INTRODUCTION

Poor road surface conditions create situations that are potentially dangerous to motorists, vehicles, people, and property. Monitoring the road condition is critical to the improvement of safety in roads, lowering accident rates, and protection of vehicles from getting damaged as a result of poor surface road conditions. Reports from the national crime records bureau states that 30 people are killed in road accidents due to poor road conditions each day. Governments worldwide spend millions of dollars on maintenance and repair of road surfaces. Traditionally, the Governments engage manual inspection teams that perform physical examination of road surface conditions with the aim of identifying bumps and potholes [16]. Manual approach tends to be irregular and highly unreliable since there are multiple factors at work that can constantly or immediately cause damage to the infrastructure [23]. Therefore, automated monitoring processes like pothole and bump detection [8] is much more beneficial for both road users and the Government. Using advanced vehicular technologies [21] especially, vehicular communication combined with sensing technologies and Global Positioning System (GPS), road anomalies can be easily identified [2].

Section II sub divisions A, B, C explains about the factors affecting the road infrastructure. Section III delves into detail about the methods used to detect the road surface condition. Section IV is a comparative analysis of the previous methods.

II. FACTORS AFFECTING ROAD INFRASTRUCTURE

A. Climatic Condition

Heavy rainfall weakens the road structure severely. Since road materials can be easily damaged if continually exposed to water and flooding, climatic condition is a major player in damaging the infrastructure. Especially, in tropical countries where alternating weather conditions prevail, the extreme change in weather damage roads. [23] [19]

B. Loading

Heavy vehicles induce a lot of pressure on roads primarily made of inelastic material forcing it to break. Large trucks that carry huge weights at a time and usually move at a slow pace increasing the pressure applied on to the road while travelling. [19]

C. Traffic volume

Traffic volume is one of the largest factors that affect the roads. India, the country with the second largest road system, has rural and narrow road in most of its land space.

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Furthermore, the country has a dense motorist population that exerts undue amount of pressure on these roads. Even with the abundance of roadways, a large part of them are tolled roads. Non-tolled federal roads are favoured over them in order to avoid the toll cost and the more travelled federal roads damage more easily. This also causes high levels of traffic due to congestion. This slow-moving traffic and the low vehicle speed increase longitudinal deformation of the road surface. [19]. [5] proposed a system about Efficient Sensor Network for Vehicle Security. Today vehicle theft rate is very high, greater challenges are coming from thieves thus tracking/ alarming systems are being deployed with an increasingly popularity .As per as security is concerned today most of the vehicles are running on the LPG so it is necessary to monitor any leakage or level of LPG in order to provide safety to passenger. Also in this fast running world everybody is in hurry so it is required to provide fully automated maintenance system to make the journey of the passenger safe, comfortable and economical. To make the system more intelligent and advanced it is required to introduce some important developments that can help to promote not only the luxurious but also safety drive to the owner. The system "Efficient Sensor Network for Vehicle Security", introduces a new trend in automobile industry.

III. METHODS FOR DETECTING ROAD CONDITION

Road condition can be successfully detected using automated sensing techniques primarily by two techniques [17]. Both have its advantages and disadvantages over one another. They are sensing using dedicated sensors placed on the vehicle or certain stationary points on the road and sensing using android phone sensors. Sensing through dedicated sensors is discussed in section A and Sensing through sensors present in android smart phones is discussed in section B.

A. Dedicated sensors

Dedicated sensors are usually units inserted with the sole purpose of sensing and collecting data as per the purpose. For road surface monitoring various sensors are inserted either on the vehicle as an on-board unit or at various stationary points along the road, that communicates with the vehicles within a radius surrounding that road side device. Dedicated sensors tend to have higher accuracy but each sensor usually pertains to one purpose only which might complicate the devices if multiple parameters are to be sensed, since that would require multiple sensors.

B. Phone sensors

With the advent of affordable smart phones, the sheer number of smart phones present in most countries is almost proportional to the number of people in it. Even the most basic version of smart phone has multiple sensors present in them such as accelerometer, magnetometer, thermometer, barometer, proximity sensor and gyroscope. Since it is easier to use a device with the required sensors, the android device itself is used. Though, android devices present on the person rather than the vehicle might collect data, which might be less accurate since it isn't interfaced directly to the vehicle.

IV. LITERATURE SURVEY

CarTel [3] is a system that uses a set of sensors installed in the vehicles itself directly to collect and process data and send it to the server using continuous queries and is processed to generate the needed data. [11] The sensors used are GPS for monitoring the movements of vehicles. The system consists of a unique structure less communication method to transfer information. The data collected is used for route planning. This system stores all the information gathered centrally and processes the data using the data stored in the cloud.
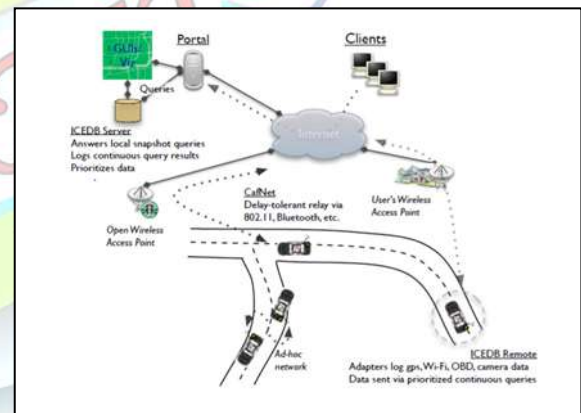

Fig. 1. System architecture - CARTEL

Pothole Patrol system [7] consists of an accelerometer that uses three axes positioning for measurement and a GPS module on the vehicle itself. It finds the damages in the road surface using the information gathered from using machine learning on the collected accelerometer data. It uses the threshold value to identify potholes based on the values of each parameter. It classifies the data by location to filter out faulty values by comparing values from the same location.
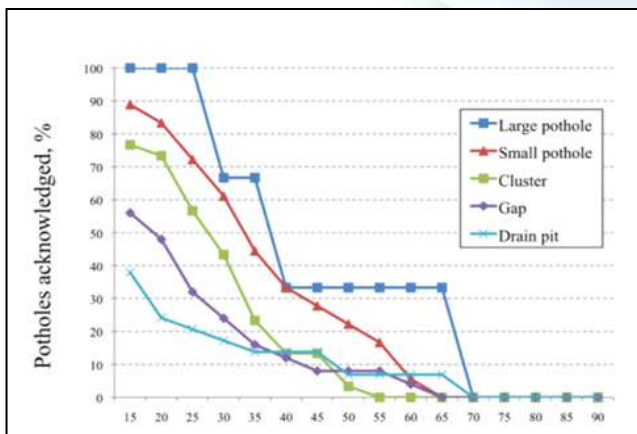
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For this purpose, a GPS device is used to detect the location of potholes.

RCM-TAGPS uses three-axis accelerometer [22] and GPS to collect data. The data is cleaned before processing to deal with the GPS error and transmission error. The Power Spectral Density (PSD) is used to detect pavement roughness using Fourier Transform and by calculating the International Roughness Index (IRI) based upon this PSD.

Nericell [14] is a system that uses sensors in the smart phones to detect road surface defects such as depressions, jerking and beeps using accelerometer, GSM radio, microphone [12] [13], and GPS in the mobile phones. Its locates the area using this GPS and GSM module on the mobile phone and the location with highest level of disturbances, where the defect parameters mentioned above are sensed the most is identified according to the information sensed. The accelerometer on the phone may not be in sync with the movement of the vehicle so it has to be changed in accordance to the vehicles direction of movements. Jerking is analyzed with the y-value of accelerometer It detects bump based upon the z-value of accelerometer. It also detects the honks using the microphone present in Smartphone.

In the paper," Real time pothole detection using android smartphone with accelerometer", [1] [15] there are no dedicated sensor but piggybacks on the phone accelerometer for potholes detection. This system proposed has multiple algorithms to fulfill its purpose of detection of data, offline processing of the collected data. The data is processed and classified using a preset threshold value to identify the type and seriousness of the potholes. There is another set of algorithms that are involved in the processing of the data which find radical differences in collected acceleration values. Finally, an algorithm is used to derive points of a vehicle falling in and climbing out of potholes.

Vankadhara et all., [4] has proposed a system that sponges off the driver's phone sensors for road surface such as accelerometer, magnetometer, GPS, etc., The device should be oriented with respect to the vehicle [10]. The device orientation is done using accelerometer and magnetometer. The accelerometer and magnetometer each gives data from which the vectors are calculator from both respective values. These vectors are used to form a matrix which is used to align the vehicles axis with the devices axis that is the x and z axis respectively. A third y-axis is also required for this orientation which is the direction of movement. It is calculated using the phones GPS This system detects depressions and vehicular jerks [20] caused due to uneven surfaces. Sudden brakes without the lowering of speed indicate pits on the road, the driver wanted to avoid by braking, this data is calculated using the drastic differences in the y-axis value [9] The sensor data is classified using k-means clustering algorithm which is labeled manually as either smooth or bumpy and brake or not. This labeled data is used to train Support Vector Machine (SVM) for classification of data points during test phase for vehicle state prediction.

Juneja, Singh et al. [18], developed a system to monitor driving behavior that uses an allied approach with mobile phones since they contain sensors require for monitoring as one unit and since most people have phones on their person while driving. This system not only uses sensors but also the microphones since monitoring honking patterns play a major role in determining traffic and driving behavior.

TABLE 1

COMPARISON OF ROAD SURFACE MONITORING TECHNIQUES

Research	Sensor used	Dedicated sensor/android sensor
CarTel	Camera, On-Board Diagnostics device, Wi-Fi	Dedicated sensor
Nericell	Accelerometer, Microphones, GPS, GSM Antenna	Android device sensor
RCM-TAGPS	Accelerometer, GPS	Dedicated sensor
Pothole Patrol	Accelerometer, GPS	Dedicated sensor

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Real time pothole detections using android smart phones and accelerometer	Accelerometer	Android device sensor
Wolverine	Accelerometer, Magnetometer, GPS	Android device sensor

IV. ANALYSIS

From analyzing the above-mentioned methods, it is found that methods that use dedicated sensors have better efficiency to that of methods using android device sensors. But, they do have their drawbacks in terms of cost and installation of these sensors to the on-road units. Whereas, the android sensors have an advantage of less cost, since most people have Smartphone's. Also, they don't need installation on the vehicle itself. But, this also proves to be a disadvantage since the inaccuracies encountered in this method also stem from the sensors not directly place on the on-road units.

V. CONCLUSION

With nearly 10,000 deaths in three years due to bad road surface maintenance, road surface monitoring has become essential to prevent more loss of life. Road monitoring can also predict patterns in road deterioration which promotes better and more suitable road management techniques. This paper analyses the methods and sensors used to perform road surface condition monitoring. It is inferred that the most frequently used sensors are accelerometer and GPS. From the research activities, it is apparent that this area will gain more importance in recent future. There are several research issues, regarding data collection and data segregation. Furthermore, machine learning used to counter this particular issue is complicated in itself. Accuracy of the data is also unpredictable in case of Smartphone sensors. Improving upon these minor issues can provide a more robust system in the future.

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