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Methods For Asphalt Polymer Pavement Surface Monitoring: A Review

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Abstract

Bitumen, also known as solid asphalt, is an intricate blend of organic molecules obtained during the distillation of crude oil. The chemical composition of it varies based on its origin, processing techniques, and intended use. Development in transportation sector led to increase the traffic volume in past year. Increase in the number of vehicles have tendency to deteriorate the pavement [paved or unpaved] surface due to heavy load and their repetitions. Heavy vehicle [>4 axle] has more tendency to damage the pavement, so pavement surface monitoring emerges to maintain the pavement surface. Pavement surface monitoring also helps in road safety also, as many accidents occur because of pavement distress like potholes, shoving, rutting etc. There are many methods for pavement surface monitoring, methods may be manual, and semi-manual. In this study semi-manual method is focused. In this method pavement distress images can be captured using high resolution camera of smart mobiles or tablets, in built with GPS. More than 5000 images will be captured of different types of distresses, all distresses are varied in sizes also, and of different location. These images are enhanced using MATLAB or any other software and then coded for deep learning. In deep learning method all the data set of pavement distresses are trained so that we can easily identify a new distress without any time delay. These images are also mapped on GeoSetter software, so that data set can be imported to Google earth file and that can be submitted to maintenance department for healing the pavement distress.

Keywords: Pavement distress images, polymerization of bitumen, maintenance, geosetter, deep learning method

INTRODUCTION

Bitumen primarily consists of hydrocarbons, which are organic compounds composed of hydrogen and carbon atoms. These hydrocarbons are classified into three main groups: [1] Saturates, These are aliphatic hydrocarbons that are fully saturated with hydrogen atoms. They provide bitumen with its waterproofing properties and contribute to its durability, [2] Aromatics, Aromatic hydrocarbons contain one or more benzene rings in their structure. They contribute to the viscosity and adhesion properties of bitumen, [3] Resins/Asphaltenes, These are high molecular weight compounds that are polar in nature. They play a crucial role in binding the other components of bitumen together and influencing its rheological properties. Development of any country is recognized by the development of any transportation sector. As good as the transportation sector, more will be the export and import activity can take place. Development of transportation sector increases the number of heavy vehicles on Indian roads. Heavy vehicles cause the more damage to both bituminous and concrete pavement, damages are in terms of potholes, rutting, shoving, alligator cracking etc, these damages are more prone to accidents, so repairing of these damages will also increase the safety of the road users. Distresses on flexible pavement occur due to degradation of bitumen where bitumen can undergo oxidation when it is exposed to oxygen and UV

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radiation, which can trigger chemical reactions. Bitumen consists mainly of complex hydrocarbons. When it comes into contact with oxygen and ultraviolet [UV] light, several chemical reactions might take place, leading to its deterioration. Oxygen molecules can react with the carbon-carbon double bonds present in bitumen molecules, leading to the formation of oxygen-containing functional groups, such as hydroxyl [-OH] and carbonyl [C=O] groups. Under certain conditions, such as high temperatures and prolonged exposure to UV radiation, bitumen molecules can undergo polymerization reactions, where smaller molecules combine to form larger polymeric chains. While polymerization can enhance the stiffness and strength of bitumen, excessive polymerization can lead to brittleness and reduced flexibility. After the construction phase completed, road is opened for the traffic, but not focused on the periodic maintenance, also traditional methods prove to be costlier and time consuming. These methods also include a greater number of peoples which led to record false data. To overcome these new technologies or methods need to be introduced which are accurate, time consuming, efficient, and economical. This type of model can be possible using machine learning methods. This paper focused on new models and latest technologies than can be implemented so that maintenance of road can be done economically, and efficiently using machine learning approach and deep learning approach [1–7].

This study is used to monitor road surface quality. It is important to ensure the safety of road users [Drivers, or pedestrians], one of the main factors to ensure safety is to monitor road surface quality. If any road surface condition is worse, chances are more to meet accidents. In this study the mobile phones/ smart phones are used to monitor the road surfaces oaf Calabria, Italy. Accelerometer are installed on several vehicles to detect the potholes and bumps, and GPS is installed on these vehicles to record the actual location of that potholes and bumps. Five devices are installed on vehicles to get the data of potholes and bumps of three different pavement conditions. Severity of bumps and potholes depend upon the energy spent on that distress. One test device is used to verify the collected data and accordingly algorithm can be developed for road surface quality using smart mobiles and tablets [8].

Effect of whether is important to ensure the safety of road users, as well as the life of road also. In the harsh norther region,whether change rapidly, snowfall starts suddenly, the information of this sudden changes in whether is shared with the road users prior to their travelling so that minimum number or no person should use those roads. This can be made possible with the help of meteorological department, and a model RoadSurf is developed. This model not only record the surface temperature but also shows the road surface condition with change in temperature, and also used for intelligent traffic condition [9].

Number of vehicles on road are increasing day by day and with increase in traffic it is important to monitor the road condition for safety of road users. Heavy vehicles have the tendency to cause the more damage to pavement and the important reason for pavement distress, thus it is very important to identify the road condition accurately and to identify the severity of pavement and types of pavement distress. Pavement monitoring for paved and unpaved roads is an important process to increase the life of pavement and for the safety of drivers as well as for pedestrian. Maintenance department invest lots of money and time in collecting the pavement distress data, and then analysing them. To reduce the time and cost of maintenance, it is important to create new models for maintenance of paved and unpaved roads. This study introduces static and dynamic methods for recording the pavement distresses and improving the quality of both paved and unpaved roads [10].

Authors detect the road surface quality using GPS and accelerometer, built in mobile phone. Authorities spend lots of capital and time to investigate the road surface quality, to minimize the capital and time RoADS is developed for road surface quality. In this study Audio-visualdata technique is implemented with times domain, wavelet transformation, frequency domain and using signals from sensor to reduce the effects of speed, drift and slopes. RoADS uses the wavelet decomposition for the analyses of sensor signals and support vector machine [SVM] for pavement anomaly and for classification. Author builds real time detector for pavement condition with accuracy nearly equal to 90%. Maintenance department can get benefit to get the actual condition of pavements [11].

In this study author uses the machine learning approach and deep learning approach to classify the for the smart vehicles. To classify the road surface author collected the data set of day and night driving from different cities, dataset contains scenario of dry, wet, and icy conditions of roads.In machine learning approach SVM, KNN and K means used to classify the texture feature of the road surface from the images. And in Deep learning approach ResNet and MobileNet used to extract the features of roads from images which is classified by a softmax layer. Deep learning method proves to be more efficient than machine learning approach [12].

One main reason of the road user's accident is the pavement distress. After pavement distress [failure] pavement should be repaired as soon as possible, by the maintenance department or higher authorities directly or indirectly related to construction and maintenance of pavement. Author analysis the efficiency and performance of deep learning model. U-Net architecture is proposed for exploring road from Road Traversing Knowledge data set.This model is compared to other models which already proposed, U-net shows more accuracy than other models of about 97.08% and also efficient model comparing to other models [13].

In this study the road surface conditions of Malaysia is collected and analysed using IOT [Internet of Things] sensors and machine learning model. Road surface conditions include smoothness, uneven surface, potholes, speed bump and rumble strips are collected and analysed. Statistical features such as skewness, median, average, standard deviation, maximum and minimum are included, both time and frequency domain frame. Road surface features is analysed using K-NN, RF, SVM, PSO, Ranker and Greedy algorithm shown in. Authors model is able to achieve 99% accuracy [14].

Researcher uses the low cost machine learning to solve road surface condition, road traffic condition, and attitude of driving. For the safety movement of the vehicles many automobile industry uses Ethernet and Controller Area Network [CAN], these network collect data from engine, brake, transmission etc. Random Forest [RF], Decision tree and Support Vector Machine [SVM] are used by the author to drive algorithm to predict the road surface condition as low, medium and high severity and also the attitude of driving as aggressive and calm. Researcher shows that RF proves to be better with a high accuracy between 92% to 95 % [15].

Researcher presented the use of deep learning method and formed a new algorithm based on Rectified Linear Units [ReLu] activation function. Traditional method of image recognition not proved to be a better method based on the performance, real time data, accuracy and efficiently, so deep learning method overcomes all these shortcomings for image recognition. This new developed algorithm by the researcher shows the accuracy of 94.89%. Researcher also suggested that CNN will proved to be better [16].

Author in this study uses the common technology smart road sense for detecting the road surface condition of Salerno, Italy using GPS and triaxial accelerometer in built in mobile devices. In this study the smart road sense survey is conducted on Provincial Road[SP 2] of Salerno in Italy and these distresses is compared with distress Cadastre data of the same province road. Smart road sense system is efficient and vary with the distress type and system proved to be efficient in monitoring the different types of road failures. Identification of road failure helps in the maintenance of roads to achieve safe and comfortable ride [17].

STUDY

Work of previous researcher's are tabulated in the table1, and comparison is made to find out the new method for the pavement monitoring system, in many study type of pavement is not mentions so it is assumes all types of roads, new method should be economical, and time consuming as well as works in real time.

From the above studies, we can go for deep learning method for the pavement distress monitoring. Pavement distresses image can be captured using high resolution camera, and the high accuracy GPS is

used to record the accurate location of the distress. High resolution camera with in built GPS can be used, to minimize the carry bags of devices or high resolution smart phones can be used. Captured images can enhanced using MATLAB or Pycharm, then collected data is trained using deep learning method. After trained data set, it is easy to map the captured images on GeoSetter software and Google earth file can be imported and used for maintenance purpose. Later on trained data set used for upcoming distresses and provide the different repair method based on the severity of distresses.

COMPARISON IN DETECTION TECHNIQUE

In order to identify road surface monitoring, several vision-based approaches and monitoring systems use image processing and deep learning technologies on videos or images as input data. Table 1 provided the many methods that have been applied for estimating the detection of road surface cracking in various nations. However, the vision-based method has limits in terms of figuring out the volume and depth of road surface cracking because it only employs two-dimensional data.

Table 1. Summary of previous pavement monitoring systems.

S.N.	Pavement	Monitoring system	Used devices/ techniques	Case study area	Reference
1	Urban roads	Dynamic	Smart phone, GPS	Calabria [Italy]	Vittorio et al. [2012]
2	All roads	Static	RoadSurf, Forecast models	Finland	Markku et al. [2015]
3	Paved and Unpaved	Static and Dynamic	Study of previous devices	Australia	Amir et al. [2020]
4	Local roads	Dynamic	Support Vector Machine, smart phones and GPS	Albania, Netherlands	Fatjon et al. [2016]
5	All roads	Static and Dynamic	SVM, KNN, ResNet and MobileNet	Austria and Chine	Huan et al. [2022]
6	Asphalt [Paved and unpaved]	Static and Dynamic	UNet, RTK	Indonesia	Robet et al. [2022]
7	All roads	Dynamic	KNN, SVM, RF, PSO	Malaysia	Jin et al. [2019]
8	All roads	Dynamic	RF, SVM, Decision tree and CAN	Jordan	Ghaith et al. [2022]
9	All roads	Static	Deep learning, Image recognition	China	Lushan et al. [2019]
10	Provincial Road [SP2]	Dynamic	SmartRoadSense, GPS, triaxial accelerometer	Salerno, Italy	Francesco et al. [2021]

In terms of detecting techniques, there are three different sorts of methods: Type A is the vision-based method; Type B is the vibration-based method; and Type C is the 3D reconstruction-based way. Previous research clearly shows that the crack features derived from the different convolution layers of the deep convolution network are not identical. Thus, in order to conduct a comprehensive analysis of fracture features and raise the accuracy of pavement crack recognition, it is essential to thoroughly extract their features by deepening the convolution network.

CONCLUSION

Road surface monitoring is an important task after the construction phase gets completed. Road surface monitoring also helps in the safety of road users in terms of drivers or pedestrian. As much as the road free from anomalies less probability of accidents and the damage of pavement. Using road surface monitoring methods safety of road users is enhanced and life of pavement can be increased at the same time expenditure on severe distresses can be minimised.

Deep learning method can be used to train the data set [pavement distress images], and this developed method can be used to identify pavement distress based on severity and also provide the different repair

methods for the present distresses and also for the new distress. This method also used to predict the distresses of pavement likely to be occurring.

This study will prove better instead of using the conventional method of pavement surface monitoring. It also helps in the safety of road users whether it is surveyor or the driver or any other person using the same road, more the pavement is free from distresses more will be safer.

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