

A Survey on Road Condition Monitoring and Mitigation

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Abstract

Condition monitoring of the road is a challenging task as the road conditions can be associated with the correct road position, making it possible to use the information in many different applications. They include autonomous navigation of Unmanned Ground Vehicles (UGVs) in defense and civilian traffic monitoring for various weather conditions. The road condition monitoring can be implemented in real time using cloud technology and suitable Artificial Intelligence (AI) algorithms such as Artificial Neural Network (ANN) to classify the nature of the road surface. The heterogeneous sensors to sense the environmental information are networked together to form a distributed sensor network on board. The sensor data will be deployed into the cloud as web service messages. The sensor data which will be integrated can be monitored in the cloud for hindrance free navigation.

Keywords: Cloud, Navigation, Sensors, Web Services, Image Processing and Artificial Intelligence.

Introduction

A healthy and good roadway is essential for the socio-economic development of the country. It is generally observed that if road deterioration is allowed to increase, the economy will significantly have larger expenditures in the forth coming years to keep the road maintenance backlog constant. Online Image based monitoring of road surface conditions during and after a snow storm, heavy rain or any other climatic condition is essential for most transportation agencies as it the responsibility of the Government to provide maintenance for the road under the circumstances of bad weather conditions. Information from road surface conditions can be used to infer the need for maintenance service, compare the effectiveness of different treatment methods, and evaluate the quality of the maintenance services delivered by contractors across different maintenance yards.

Real time information on road surface conditions is of great importance to the road users who can use the information to improve the travel by taking appropriate driving decisions based on the mode of travel. Currently, monitoring of winter

road surface conditions is mostly done through personal observations and manual recording, which is limited in repeatability, details and timeliness. In India the road conditions need to be monitored in the hilly areas, snow cover regions and in the military areas where the security is high. A web based surveillance video of the snow and ice cover can be sensed by sensors which have new opportunities for quick and objective assessment of road surface conditions as they are costly for implementation and limited in spatial range and completeness. The proposed work will be further advanced with new Intelligent Image based road condition monitoring solution with innovative features and data fusion techniques on a platform of cloud based wireless and Internet technologies. The sensor data are processed onboard and will be transmitted to a central server where data from a number of participating vehicles will be processed to generate road surface condition information that is of high spatial, temporal and lateral coverage.

The networking of sensors will be a distributed event based system that focuses on simple data gathering applications. The gathered data can be made accessible to other nodes, including a specialized one called sink [2] through a variety of means. This distributed System for information gathering performs data intensive tasks such as condition monitoring, Terrain monitoring and Surveillance [3]. The elements required for this will be a Sink which sends queries and collects data from sensors. The other is a Sensor which monitors the phenomenon and reports to the sink. This is depicted in Figure 1. In the proposed work the sensor networks are envisaged as comprising heterogeneous devices. Interoperability is required for such heterogeneous devices. To achieve this Service Oriented Approach (SOA) for the data acquisition from sensor network, is proposed and an extensible architecture in which this web services based deployment is extended to CLOUD. Here the sensor nodes are service providers and applications are clients of such services.

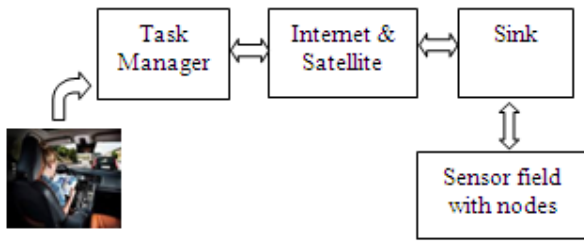


Fig. 1. Cloud based Monitoring

Cloud computing is a style of computing in which virtualized resources are provided as a service over the Internet. They serve as virtual servers and on demand, add and subtract processors, memory, network bandwidth and storage for real time processing of heterogeneous data sources in order to make critical decisions. To increase the robustness of the system AI based object recognition [4] are used. They are needed to offer sturdiness due to the imprecision and uncertainty in the Sensor readings. It also requires low computation time which favours the battle ground situations. The organization of this paper is as follows: Section II gives a survey on road condition monitoring system. Section III presents a novel method to monitor and detect road conditions. Section IV defines objective of this paper. Section V describes the system design and conclusion discusses in Section VI

II LITERATURE SURVEY

The researchers at University of Waterloo have developed [8] and demonstrated a machine vision and AI based road condition monitoring system in winter season that will allow the use of inexpensive, non dedicated hardware such as high resolution cameras and temperature sensors to gather, process and transmit road condition data in real time. In comparison to the existing solutions, the proposed system can be installed on any vehicle, provides more objective assessment of road condition, and delivers better spatial and temporal coverage of condition monitoring.

The initial development focus was towards testing the developed algorithms on secondary image data collected for other research projects. In the last two years, a purpose built in vehicle data collection system has been developed and is being improved upon. On the server end, an image processing application has been developed to communicate with in vehicle units, store and process image data and show live status updated on the computed road condition status. With the help and support of the Ministry of Transportation Ontario (MTO), the system has been deployed and tested on actual patrol vehicles and over 10, 000 data points have been processed with promising results. For any transportation weather decision system Mobile weather sensors are an important element. Mobile systems detect key parameters as a vehicle moves along the roadway, giving the user information over large areas. The mobile systems can be connected to data collection networks, allowing a user to view the data from many vehicles at a single location.

The Vaisala Condition Patrol DSP310 is the first solution available to monitor road weather and provide maintenance. The Condition Patrol monitors pavement condition, friction or grip, pavement temperature, air temperature, and moisture in the air. There is flexibility in this system for the users as the data is accessed and monitored so that it can be viewed in the vehicle or in the control room. Mobile road weather data collection is done by capturing air temperature and pavement temperature. The Vaisala Surface Patrol is equipped with Temperature and Humidity Sensor to measure atmospheric temperature and atmospheric moisture. Monitoring dew point is very important in road weather because it gives idea regarding worst and favorable conditions during the formation of frost or black ice on the road surface

Fixed road weather stations are the perfect solution to monitoring road conditions. Adding weather sensors to vehicles is the solution. The Vaisala Surface Patrol Pavement Temperature Sensor is a perfect low cost, highly reliable sensor designed specifically for mobile use. From the technical report [1] it is evident that there is a significant correlation between traffic accidents and slippery road conditions. Classification of slippery road conditions has been the subject of high intensity research work for few years. Estimation of slippery road conditions on line in a vehicle can be done by incorporating a device which would benefit both the driver as well as systems in the vehicle like the Anti-lock Braking System (ABS), Traction Control System (TCS) and the Stability Program (SP). Since the slippery road condition monitoring is of great advantage as the slippery road information can be sent to a server would increase the information dissemination for more than just one vehicle. For near infrared wavelengths of light it has been shown that the spectrum of water, ice and snow are distinguishable [2, 3]. Nowadays there are a number of optical prototype sensors for classification of road conditions. Two techniques that don't use any additional illumination is a Stereo camera system combined with image processing [4] and a technique where the ratio of incoming and reflected light is measured with two pyrometers [5]. Both techniques are dependent on street lights or oncoming vehicles during night time to work properly, which makes the method complicated. However, the large monitoring area of the stereo camera system is an advantage. A third technique, the one that is used in this investigation, is based on laser diodes of different wavelengths and a photo detector [6, 7]. The wavelengths are chosen because the differences in absorption between water, ice and snow are specifically large in their spectral bands and that cheap off the shelf laser diodes are available in these frequencies. In Swedish and EC funded projects [7] the optical sensor uses the laser diode technique and has been modified. The off the shelf laser diodes make the sensor competitive in price as well as in performance. The focus of this paper is to show how slippery road conditions could be classified and how this information could be presented.

Their experimental results from real urban driving data demonstrate the usefulness of the system. Their contributions are: 1) Performing a throughout spectral analysis of tri-axis acceleration signals in order to get reliable road surface anomaly labels. 2) Comprehensive preprocessing of GPS and acceleration signals. 3) Proposing a speed dependence

removal approach for feature extraction and demonstrating its positive effect in multiple feature sets for the road surface anomaly detection task. 4) A framework for visually analyzing the classifier predictions over the validation data and labels [7].

The proposal describes a road condition monitoring and alert application using the in vehicle Smartphone as connected sensors, which are connected to an Internet-of-Things (IoT) platform over the Internet. In addition to providing a generic IoT based platform, the proposed solution brings in novel energy efficient phone orientation diagnostic accelerometer analytics in phone, reduces the data volume that needs be communicated between phone and the back end over Internet, brings in multi-user fusion concepts to create authentic road condition maps and addresses privacy concerns for the phone user for sharing the required data.

A study by US Federal Highway Administration has shown that road condition is an essential factor of highway quality and smooth roads will lead to more comfortable driving experience and less municipal investment. International Roughness Index (IRI) has been widely used to measure pavement smoothness because it can provide a consistent rating for different measurement tools. However, existing measuring tools based on IRI are usually very expensive. In this paper, we present a low cost vehicle based solution, Road Condition Monitoring with Three-axis Accelerometers and GPS Sensors, by using a cheap three-axis accelerometer and a GPS sensor embedded in a vehicle to monitor the road condition.

A well maintained road network is a must for the economic development and the well being of people in any country. Unfortunately, most developing countries do not pose such road networks. While the lack of funds is mainly to blame for not building new road networks and maintaining the existing ones the lack of proper monitoring and reporting system is a major contributory factor for the dilapidated condition of road networks in third world countries. A case in point is the road network in Sri Lanka; Sri Lanka has an extensive road network that spans the country and new roads are being built every day, yet even the roads in the capital city are not maintained properly. The lack of a monitoring and reporting mechanism is apparent in this case [8].

A public transport system based sensor network to monitor road surface condition is proposed here. We are currently building such a network called Bus Net to monitor environmental pollution and that system can be extended for road surface condition monitoring by adding acceleration sensor boards to the system. Monitoring of winter road surface conditions during and after snowstorms is essential for most transportation agencies to assess the need for maintenance service, compare the effectiveness of different treatment methods, and evaluate the quality of the maintenance services delivered by contractors across different maintenance yards. Real time information on road surface conditions is also invaluable to the road users who can use the information to improve their travel and driving decisions such as where, when, and in what mode to travel [8, 9]. Well maintained road network is an essential requirement for the safety and consistency of vehicles moving on that road and the wellbeing of people in those vehicles. On the other hand,

guaranteeing an adequate maintenance by road managers can be achieved via having sufficient and accurate information concerning road infrastructure quality that can be as well utilized concurrently by the widespread means of users' mobile devices both locally and worldwide. This article proposes a road condition monitoring framework that detects the road anomalies such as speed bumps. In the proposed approach, the main indicator for road anomalies is the gyroscope around gravity rotation in addition to the accelerometer sensor as a cross-validation method to confirm the detection results that were gathered from the gyroscope [7].

The problems associated with safety, economy, and overall quality of road transportation are influenced by the characteristics of both roads and vehicles and by the manner in which these two systems interact. The vehicle road interaction problem has been largely used as a platform for investigations into the mechanics of vehicle induced road damage, road-induced vehicle damage and ride comfort. The nature of the interaction is also perceived to negatively affect the vehicle's fuel consumption and driver performance. Studies show that these problems increase with more roughness on the road surface (OECD Expert Group, 1994 & 1998; Cebon, 1999). Thus a critical issue has always been to avoid serious deterioration of road infrastructure by implementing a condition triggered maintenance schedule. Highway Design and Maintenance (HDM) model was developed to optimize the economic benefits given by road maintenance. However, HDM cannot be applied directly within any local operating conditions for the first time without some sort of calibration (Rohde, Zooste, Sadzik, Henning, 1998; Caroff, Freneat, Riviere, Spemol, 2001; Jain, Aggarwal, Parida, 2005). Secondly, HDM is largely viewed as World Bank tool for evaluating the viability of road maintenance, rehabilitation and construction projects, and as such, it might be largely used in situations where justification is required to solicit World Bank funds. Besides, HDM model still require road condition parameters obtained from good road inventory (Tsunokawa, Ul-Islam, 2007) often collected through visual inspections or using one of a limited number of instrumented vehicles. It is therefore necessary to develop alternative methods of assessing the integrity of roads [10].

In order to achieve that, it is necessary first to obtain a correct road surface profile. There are many methods reported in the literature for obtaining road profiles by direct measurements of the road itself (Sayers, Gillespie, Paterson, 1986; Cundill 1991; Sayers, Karamihas, 1998). However, Gonzalez, O'Brien, Li, Cashell (2007) argue that such methods are expensive hence they present a numerical validation of a method for estimating road roughness using the accelerations obtained on the vehicle body and axles.

The road roughness is expressed as a function of Power Spectral Density (PSD) according to International Standards Organization (ISO) classification (ISO 8608, 1995). The recent developments in vehicle design where accelerometers are being mounted on chassis systems in order to improve suspension performance makes this technique relatively inexpensive. This method totally focuses on the mechanical systems present in the vehicles and how they are influenced by the surface of the road.

III PROPOSED SYSTEM

This paper presents a novel method and evaluation results to monitor and detect road conditions (ice, water, snow and dry asphalt). The developed device based on light polarization changes when reflected from road surface. The recognition capability has been improved with texture analysis which estimates contrast content of an image. Test drives are performed with a vehicle equipped also with a commercial solution from Vaisala which was used as the reference sensor. The results show that the proposed solution does not currently adapt to different conditions perfectly well. Therefore, further development targets have been identified to include not only more adjustable classifier but externally lighting to stabilizing ambient illumination.

IV OBJECTIVE OF THE WORK

The objective of this research is to improve traffic safety through collecting and distributing up to date road surface condition information using mobile phones. Road surface condition information is seen useful for both travellers and for the road network maintenance. The problem we consider is to detect road surface anomalies that, when left unreported, can cause wear of vehicles, lesser driving comfort and vehicle controllability, or an accident. In this work, the basic idea is to develop a pattern recognition system for detecting road condition from accelerometer and GPS readings.

V SYSTEM DESIGN

In this paper a model is presented, which combines the concept of sensor networks with the cloud computing paradigm, to monitor the road conditions and offer smooth navigation of the vehicles. The cloud computing strategy [3] is already been evolved to identify the effective ways to capitalize and take advantage of cloud computing benefits in the defense industry. The cloud monitoring system is shown in Figure 2.

A. Proposed Monitoring of the traffic – Through Cloud

It is proposed to use Service Oriented Architecture (SOA) for accessing the sensor information present in the vehicles on road. This is extended to Cloud architecture for monitoring the road conditions. All these data are converted into web service messages and are integrated into cloud for further monitoring and control the various vehicles on road based on road conditions which is shown in Figure 3. This in combination with the fact that the four road conditions, wet, icy, snowy and asphalt, also have different light scattering properties makes light ideal to use for a sensor that estimates slippery road condition.

B. Sensing through SOA

The needs of sensors are necessary for monitoring the environment at precision. Here the sensors installed transmit the message through GPS [4]. A client application querying the data to the sensor network plays the role of service requestor. Sink node acts primarily as a service provider to the external environment. Then sink implements transformation

and mapping algorithm to transform the sensor data into a user friendly format for internet accessing. The sensor data is sensed from sensor node in the form web service message. The sensor data which are sensed from the sensor node is updated on sensor base. This will be useful for performing the future statistical analysis. The client application sends a Simple Object Access Protocol SOAP request message for a specific service to sink by the application running on the sun application server.

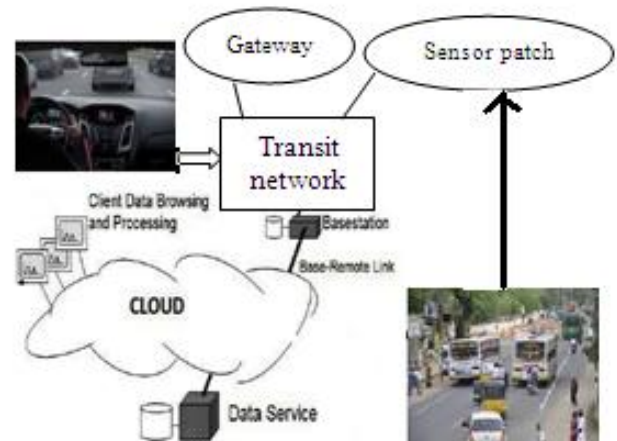


Figure 2. Cloud based monitoring - overall system

Thus we ensure that the data packets are bounded to an group rather than particular node. Thus the data can be addressed by the area name.

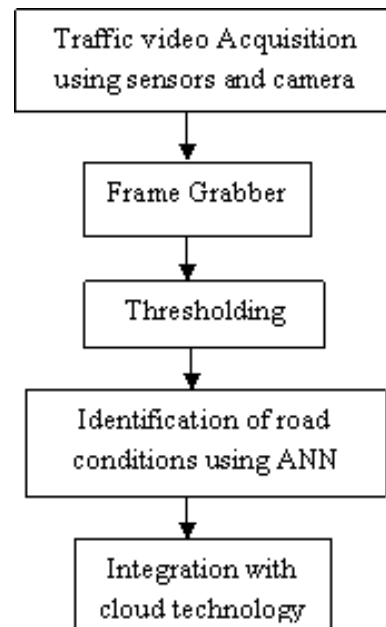


Figure 3. Cloud based road monitoring and traffic controlling system

C. **SOA extended to Cloud for access and monitoring**

Sensor networks collect information about the physical environment, but typically lack the resources to store and process the collected data over long periods of time. Cloud computing elastically provides the missing storage and computing resources. Specifically, it allows to store and access the collected sensor data effectively via Cloud based services. Cloud computing is a way to increase capacity or add capabilities on the fly without investing in new infrastructure, training new personnel, or licensing new software. Sensor resources do not have direct connection with cloud. Hence, a framework is necessary to manage the data from the sensor network and take it over long environment. In this section, SOA architecture is extended to cloud by using Integration Controller which acts as a bridge between the two technologies. In this architecture the Integration Controller (IC) will upload the sensed data to the IBM Bluemix Cloud. It Supports complete sensor data life cycle from data collection to the backend decision support system.

D. **Intelligent Image Recognition for Traffic Monitoring**

The first step includes the collection of the road images under various weather conditions. They include asphalt, water, ice and snow covered on the surface of the road which inhibits the navigation of the vehicles.

The second step involves performing morphological operations like opening, closing, dilation and erosion. The features are extracted using the above said operators which can further be used estimating the road conditions.

The third step is to compare the output of the various morphological operations with the threshold value. It is process to convert the grayscale images to binary images. The purpose of thresholding is to extract the pixels from the image which represent an object. Though the information is binary the pixels represent a range of intensity values. The objective of binarization is to mark pixels that belong to true foreground regions with a single intensity and background regions with different intensities. There are two types of thresholding algorithms. The choice of the threshold value can be either manual or automatic. They are as follows

Global thresholding algorithms

Local or adaptive thresholding algorithms

Based on the output value obtained it is possible to classify the road conditions. The conversion is shown in Figure 4. Finally the nature of the road surface can also be classified using various ANN algorithms to which the features from binary images will be used as inputs.



Figure 4. Block Diagram for grayscale to Binary image Conversion

E. **Sensor as Service at cloud**

To monitor the sensor data from the vehicles, IBM Bluemix cloud environment will be used. Based on the sensor parameters the road conditions will be monitored and the navigation of the vehicles will be controlled. IBM Bluemix [7] is an open standard, cloud based platform for building, managing, and running applications of all types, such as web, mobile, big data, and smart devices. Hence it is used for cloud based monitoring of the road conditions using onboard sensors in the vehicles.

Conclusion

This study helps to automate the navigation of vehicle technology from the cloud environment using service oriented sensor parameters. During the test runs the movement of the vehicles achieved to certain level with visible corrections from the control system will be used to avoid traffic congestion. Sensor data access is moved from loosely managed system to a well managed cloud. The cloud monitoring environment leads to the concept of green engineering, because it offers a massive storage of sensed information from various vehicles on road at a distance place, for future analysis which makes it very attractive.

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