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Review and Analysis of Acceleration Vibration Signal Processing Methods for Road Surface Monitoring

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Abstract: *Identification of the road surface anomalies and roughness levels is essential for the proper monitoring, which inturn improves the driving comfert and passenger safety. Several methods based on Image Processing and signal processing has been used to monitor the road surface conditions such as existence of potholes, humps, and road roughness. It includes 3D Re-construction, Vision based detection, Ultrasonic sound based detection and Vehicle vibration analysis. These methods may contribute to not only the prior information to the passengers and also improves the survey efficiency of the authorites and road surface quality through prior investigation, precaution and immediate action. In this study, we try to investigate and analyze different road surface irregularity monitoring methods based on vehicle vibration which have developed and propose to fullfil the requirement of passengers and muncipal authorities about the information regarding the presence of road distresses such as pothole and hump*

Index Terms: *Accelerometer, Kalman filter, Gausisan Mixture model, Pothole and Hump detection, Double integration*

I. Introduction

In this ever fast moving world everybody is looking to reach their destinations as early as possible. The major limitation to this dream is the improper, irregular roads. The drivers are not able to drive their vehicle with a regular speed due to the sudden existence of hazardous pothole and humps on the road. This also causes severe damage to the vehicle and also to the health of the passengers. An efficient method is necessary to detect the presence of such irregularities mainly potholes and humps not only to inform the drivers, it also helps the authorities to update the road conditions in a faster manner.

In the past decade there were several methods came into picture for the detection and identification of such distresses on the roads. Most of them uses the image processing approach. 3D Laser Scanner Methods[1] a technique that employs re-flected laser pulses to create accurate digital models of existing objects Severity and coverage of distress such as potholes can be accurately and automatically quantified to calculate the needed amounts of filled materials. Stereo Vision [2] exploits the images from two different cameras to obtain the existence of pothole. Kinect based approach also uses the images of the road to detect the irregularity event. The latter is cost effective compared to the former two methods. An Ultasonic Sensor based[3] Pothole and Hump detection was proposed by Rajeswari et al. where the depth and height of such irregularities were estimated by measuring and processing the reflected sound wave from the road surface.

Even though these approaches try to identify the presence of pothole and hump, these techniques are very expensive in nature and it cannot apply to middle class level vehicles. Another issue with the above techniques is the real time processing, this also leads to some very complex algorithms which needs high computational capability devices. With this as our major objective we try to ivestigate on different aproaches on another road surface monitoring tech-nique based on vehicle vibration analysis using accelerometer vibration signals.

II. Related Works

Data aquisition and its analysis from external accelerometer sensors is a wide area of study. The same data is used for many applications like Activity recognition,Object displacement, at-itude estimation of aircrats and road surface monitoring. All these applications which use the accelerometer data are somewhat related.So the main focus of this investigation is to relate all those technique and find out an efficient method for detection of road surface irreguarities such as pothole and hump.

J.L Verboom et al.[1] presented a method for the estimation and control of Attitude and Altitude of a Flapping Wing Micro Air Vehilce. In this work they have used the raw acceleration data to extact the attitude information of the MAV. This data is pre-processed with moving average filter to remove sudden unwanted variations. Faemeh et[2] al. have used the accelerometer data to find the 3D orientation of any object. They have exploited the Trapezoidal integration method for the extraction of position information of the object.They have also utilized the kalman filtering[3] to estimate the present state of the oject by looking at the previous states. The method by Li Fang, Shui and Chen Wei[4]have used the smartphone accelerometer data for the up and down human ac-tivity recognition in buses. A combination of the time domain and frequency domain analysing features had used to extact the human movement from the raw accelerometer data.By using a KNN classifier they have achieved an efficiency of 95.3%. A similar aproach have been developed by Xing su et al.[5] for all the human activity recognitions using smartphone accelerometers.

Rong Liu[6] et al. have designed a microproccesor based portable device that includes accelerometer to detect small displacements.The data is pre-processed using Butterworth IIR low pass filter which is then double integrated to obtaion the displacement. The application note of Free scale semi-conductor[7] explains the detailed implementation of posi-tioning algorithms using accelerometers.MMA7260QT a 3-axis accelerometer data is applied with trapezoidal method to extract the displacement.

The remaining portion of this review concentrates on the various methods of applications of accelerometer vibrations for road surface analysis.Jinwoo et al.[8] proposed a system which uses a data logging algorithm in each vehicle clients where the algorithm records the data only when the RMS values of acceleration exceeds the threshold.The data is fragmented into Impulse class, Rough class and Smooth class based on the vibration data. Paper[9] presents a noval vibration based approach for automatic detection of potholes and speed breakers along with their GPS co-ordinates.Irregularities are classified on the scale of 1 to 3 based on the gravitational force produced for each pothole and hump which also depends on the vehicular speed.The coorectness of the method comes upto 93.75%.

A crowdsourcing based monitoring method by Kongyang Chen[10] uses Gaussian Mixture Model algorithm to detect a pothole event for various vehicle driving speeds.The vibration threshold is varied with driving speed changes which reduces the error introduced by the speed parameter. The raw vibration data is passed through four different filters[11] such as veloc-ity, Z-axis acceleration, X-Z acceleration and Velocity vs Z-axis acceleration to remove maximum anomalous events. They could estimate the road roughness level with an accuracy of 90%.

The research article by Yuchun et al.[11] uses a system that can obtain vehicle status and calculate international rough-ness index(IRI) by power spectral density analysis.Kazuya and akira[12] have utilized the application of lifting wavelet tranform for the pavement surface monitoring with the help of mobile profilometer(MPM). LWT enables to develop cus-tomized lifting wavelet filters to detect desirable waveform characteristics in roughness profile data.

Safe driving using mobile phones[13] by Mohamed Fazeen et al. use three-axis accelerometer of an android based smart-phone to record and analyze various driver behaviour and external road conditions.They have used the Y-axis accel-eration data in additon to obtain the vehicle speed where as all other methods have used external GPS to obtain the same.This technique reduced the power consumption by a significant amount.They have also differentiated the pothole from a hump by obtaining the correlation between Z-axis and X-axis acceleration data.

All the above mensioned road surface monitoring methods tried to update these irregularity event detections to a central server via GPS and other communication mechanisms in order to give prior alert to drivers and to alert the authorities regarding the current condition of the road.

III. Summary Of Findings

Non vibration based techniques are highly expensive. Many of them are not suitable for real time analysis. So the best cost effective and responsive method is the vehicle ibration signal analysis. The vehicle vibration and acceleration may vary in proportion with the driving speeds. It is very difficult to set a global threshold value for Z-axis reading. These vibration signals may contain measurement errors and offset values due to the force of gravity, its hard that the direct integration of acceleration data wont give us the exact displacement values

IV. Conclusion

From the literature review and its summary of findings we have found that all the exsisting road surface monitoring methods have their own merits and drawbacks. So there is a need to develop a noval road surface monitoring method using various methods that are already exsisting along with some new technologies that can not only identify and update the presence of pothole and hump but also their depth and height respectively.

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