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Pothole Detection using LiDAR

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ABSTRACT— Advanced Driver Assistance System (ADAS) are systems developed to enhance, automate and adapt with vehicle systems for safety and better driving experience.
OurADASsystemproposestodetectpotholesontheroadwhich are beyond the driver's visibility range in real-time, allowing the driver with sufficient time to react. This pothole detection is accomplished using a LiDAR sensor and detection algorithm that is runningonthe computer.This system usesa LiDAR sensor to detect apothole.LiDARisalasersensorusedtodetecttherelativedistance between the target and the sensor. We are using a LiDAR sensor packagethat providesus360'distancedatabyhavingthesensoron a rotating platform. By using a 2D LiDAR angle and distance, information about the roads isobtained.

An algorithm is designed to define if pothole is present and the location of the pothole relative to the vehicle. The algorithm of pothole detection includes clustering, line segment extraction, generation of data function, gradient of data function.

After pothole is detected, the GPS location of the pothole is obtainedusinga GPS sensor. The potholedata including the location of the pothole is then sent to a cloud database. A web application designed to mark potholes on Google Maps embedded in a custom webpage using Maps JavaScriptAPI.

Keywords—2D LiDAR, GPS, cloud, Maps JavaScript API

I. INTRODUCTION

Oneofthemostwidelyusedtransportinfrastructure areroadnetworks.Thevehiclesthatplyovertheseroads vary from cars, bikes, trucks, heavy vehicles, etc. There has been agradualincreasein volumeof vehicles inrecent year so wing to the improved connectivity between cities, villages, and towns. However, one of the major problems faced by road user sisthepresence of potholesinmajorurban and suburban roads, junctions, and various otherplaces.

Potholes are the irregular depression or patches on asphalt pavement that form due to heavy traffic, poor maintenance, weather conditions. Potholed roads are a common sight across rural and urban roadways especially during and after monsoons.
Although these potholes look small and insignificant, they have been the major cause of numerous road accidents that happen on a daily basis. According to the data by Union Ministry of Road Transport and Highway (MoRTH) almost 3,600 deaths have been reported due to pothole-related accidents in the year 2017.In 2019 more than 2,000 fatalities due to pothole related-accidents. This is a staggering number. It is frightening to know that the number of deaths caused by road accidents is far more than the fatalities causedby terroristattacks.
A solution is needed which can detect potholes in real-time and assist the driver to take appropriate measures. Real-time pothole detection is a challenging task and a problem that needs a robust solution. The challenges in detecting a pothole are: (1) Low visibility of pothole from long distance.(2) Narrow width of potholes making ithardto detect using standard resolutioncameras.

The paper proposes to implement an Advanced Driver Assistance System (ADAS) to detect potholes in real- time using a LiDAR sensor. Further we track the pothole's location by integrating GPS sensor and create a central database on cloud for pothole data which can be further used by concerned authorities to monitor the road conditions.

The LiDAR sensor module provides raw point data which is further processed by an algorithm developed to detect pothole.

II. POTHOLE DETECTIONSYSTEM

We consider a pothole detection model that is shown in Fig.1.A2DLiDARsensorismountedontopofthecarsot hat itisorthogonaltotheroadsurfaceandgivesclearviewofr oad ahead.

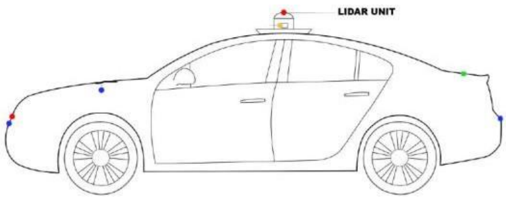

Fig.1. Illustration Model

$D_{\max} = \|p_n^h - p_{n-1}\| + 3\sigma_r.$

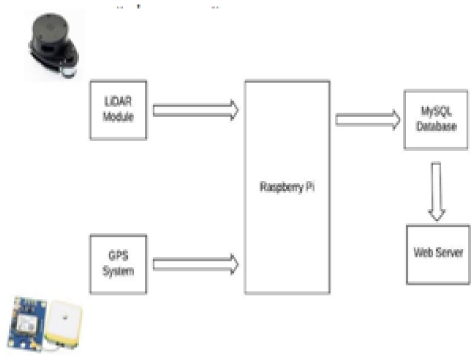

Fig.2. System Block Diagram

TheLiDARmoduleandtheGPSmodulearein terfacedto theRaspberryPi.TheRaspberryPiisconnectedtotheint ernet over Wi-Fi and accesses the database established on cloud through this connection. As per the block diagram shown in Fig.2. The LiDAR modules can stheroadaheadandprovides raw high-resolution point data to be processed. Then Processing unit Raspberry Pi receives the raw data from the LiDAR module and executes the pothole detection algorithm to determine the pothole's location relative to the vehicle. After detection of pothole the co-ordinates are received from theGPSsensor.Furtheraclouddatabaseisestablishedtos tore the pothole data with its location co-ordinates. A web application is deployed which marks the location of potholes on Googlemaps.

A. 2D LiDAR based pothole detectionmethod

Foraccuratepotholedetectionusing2DLiDARfou rsteps are performed including clustering, line segment extraction, generation of data function, gradient of datafunction.

First, the point cloud data received from LiDAR must be clustered by obtaining the distance between two adjacent points and calculating the break point using ABD(Adaptive Breakpoint Detector) method which constructs clustering by calculatingthethresholdvalueDmax.If|Pn-Pn-1|>Dmaxthen breakpoints are obtained and these points are handled as one cluster.

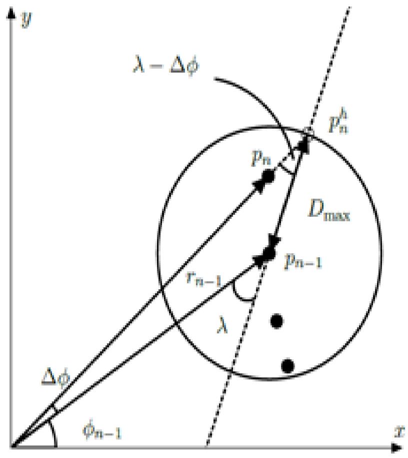

Fig.3. ABD Threshold Dmax

Here, the distance between the points pnh and pn-1 is calculated using

$$\|p_n^h - p_{n-1}\| = r_{n-1}\frac{\sin(\Delta\phi)}{\sin(\lambda - \Delta\phi)}.$$

Where, rn-1 is the range from the sensor to the point pn-1,
□□isthedistanceresolutionoftheLiDARand□isthewo rst case incidence angle used to extrapolate the largest allowed distance between successive points. Any current point Pn outside the threshold circle as shown in Fig.3 will be considered a breakpoint. If it meets thecondition
|Pnh-Pn-1|<Dmax , then the points are handled as one cluster.

Next, after obtaining multiple clusters each cluster undergoes Iterative End Point Fit (IEPF) algorithm. It is used to extract line segment for each cluster individually.

After line extraction, generation of data function is performed it generates a polynomial function f(x , y) for each extracted line segment.

Finally, gradient of data function is performed on each generated polynomial to decide the existence of pothole. Therefore, first order derivative of f(x , y) is performed. If there is a pothole, the differential waveform of f(x , y) has abrupt change in the function as shown in Fig.4. P(x1 , y1) and p(xn , yn) are the first and the last abrupt change points respectively. When pothole is existing the width of the pothole is obtainedby

$$\text{Width} = \sqrt{(x_1 - x_n)^2 + (y_1 - y_n)^2}$$

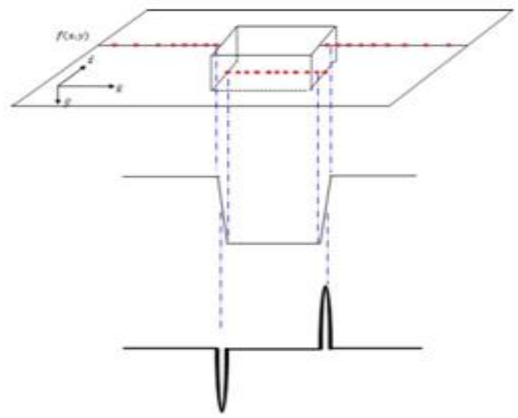

Fig.4. Variation In The Slope of The Road

B. GPSsubsystem

The GPS subsystem isacrucial part of ourproject. It is required to obtain the potholelocationdata.Anytimethe algorithmdetectsapotholeittriggerstheGPSprogramto obtain the location coordinates instantly. The coordinates data is fused with pothole data and uploaded to the cloud database.

Here we'll be using a GPS Neo-6M GPS receiver interfaced with raspberry pi to obtain latitude and longitude data.

GPS data is displayed in different message formats over a serial interface. There are standard and non- standard (proprietary) message formats. Nearly all GPS receivers' output NMEA data. Wemakeuseof$GPRMCsentencetoobtainlatitude and longitude information.

Field	Description	Format/ Value
0	The entry "GPRMC", indicating the GPS output sentence structure type	GPRMC
1	Time of position fix (in Coordinated Universal Time or Greenwich Mean Time)	hhmmss.ss
2	Status (A= valid, V = navigation receiver warning)	A/V
3	Latitude	ddmm.mmmm
4	Latitude hemisphere (N=North, S=South)	N/S
5	Longitude	ddmm.mmmm
6	Longitude hemisphere (E = East, W=West)	E/W
7	Speed over ground (in knots)	0.0 to 999.9
8	Course over ground (true degrees)	0.0 to 359.9 degrees
9	Date of position fix (in Coordinated Universal Time or Greenwich Mean Time)	ddmmyy
10	Magnetic variation	000.0 to 180.0 degrees
11	Magnetic variation direction (E=East, W=West) [west adds to true course]	E/W

Fig.5.GPRMC sentence

C. WebApplication(GMaps)

A database is created that contains pothole dataincluding its location. With this data database we plot the location of each pothole along with relevant data on a webpage which has Google maps embedded. This is a simple illustration of things that can be done using a central database that contains pothole information and a simple webserver.

To realize the above-mentioned idea, we make use of cloud service AWS where a virtual machine (EC2 instance) is initialized and on the virtual machine we install LAMP (Linux Apache MySQL Php) stack which is necessary softwareinbuildingadatabaseandaserver.TheLAMPstack contains MySQL which is a database management system which is used to store potholedata.

The basic component of this system is AWS. Amazon web service is a platform that offers flexible, reliable, scalable, easy-to-use and cost-effective cloud computing solutions.

III. RESULTS

The raw data i.e. distance and angle data of the LiDAR is receivedthroughraspberrypi0w,and it under goesclustering and thenoisydatagetsfilteredlikepointswhicharevery near to the LiDAR are removed.

Then, the clustered data undergoes the line extraction process where for each cluster a line is fitted using Iterative EndPointFit (IEPF) algorithm.

After extracting a line segment for each cluster a polynomial function for each segment is generated.

The polynomial y is the pothole data function after line extraction.In order to decide that y is potholeor not,first order differentiation of y is performed. If there is a pothole, thedifferential waveform of y has abrupt change in the function.

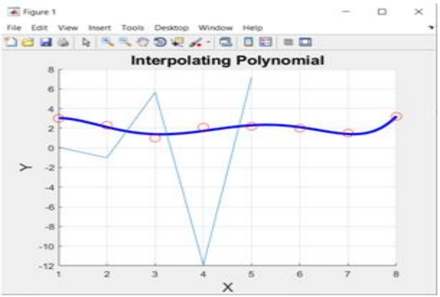

Fig.4. Cluster Existing of Pothole

The detected potholes location coordinates are obtained through the GPS module and a web application is deployed which marks the location of potholes on Google maps as shown in Fig.5.

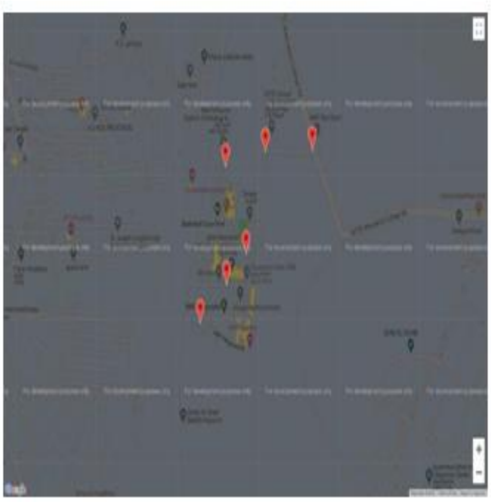

Fig.5. Webpage

IV. CONCLUSIONS

In this paper, we developed a pothole detection system using 2D LiDAR. Using the LiDAR, wide area of the road surface can be scanned more accurately. We have developed the algorithms to detect the pothole. The algorithm includes clustering, line segment extraction, gradient of data function. The proposed system of pothole detection is being executed by fixing the assembly on vehicle and the received output is given to the driver and it is added to the GMaps so that it is available for the other drivers. This system contributes in the future to improving the safety for drivers.

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