

Pothole Detection using LiDAR

Varsha Prasad^{1*}, Shivani Kumari², Suryatej I.P²

¹Department of Electronics and Communication RV Institute of Technology and Management Bengaluru, India; ²Department of Electronics and Communication Nitte Meenakshi Institute of Technology, Bengaluru, India

ABSTRACT

Advanced Driver Assistance System (ADAS) are systems developed to enhance, automate and adapt with vehicle systems for safety and better driving experience.

Our ADAS system proposes to detect potholes on the road which 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 running on the computer. This system uses a LiDAR sensor to detect a pothole. LiDAR is a laser sensor used to detect the relative distance between the target and the sensor. We are using a LiDAR sensor package that provides us 360° distance data by having the sensor on a rotating platform. By using a 2D LiDAR angle and distance, information about the roads is obtained.

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 obtained using a GPS sensor. The pothole data 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 JavaScript API.

Keywords: 2D LiDAR; GPS; Cloud; Maps javascript API

INTRODUCTION

One of the most widely used transport infrastructure are road networks. The vehicles that ply over these roads vary from cars, bikes, trucks, heavy vehicles, etc. There has been a gradual increase in volume of vehicles in recent years owing to the improved connectivity between cities, villages, and towns. However, one of the major problems faced by road users is the presence of potholes in major urban and suburban roads, junctions, and various other places [1].

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.

MATERIAL AND METHODS

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 caused by terrorist attacks [2].

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:

Corresponding Author: Varsha Prasad, Department of Electronics and Communication RV Institute of Technology and Management Bengaluru, India, Tel: 9986348199; E-mail: varshap.rvitm@rvei.edu.in

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- Low visibility of pothole from long distance.
- Narrow width of potholes making it hard to detect using standard resolution cameras.

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 [3].

The LiDAR sensor module provides raw point data which is further processed by an algorithm developed to detect pothole (Figure 1).

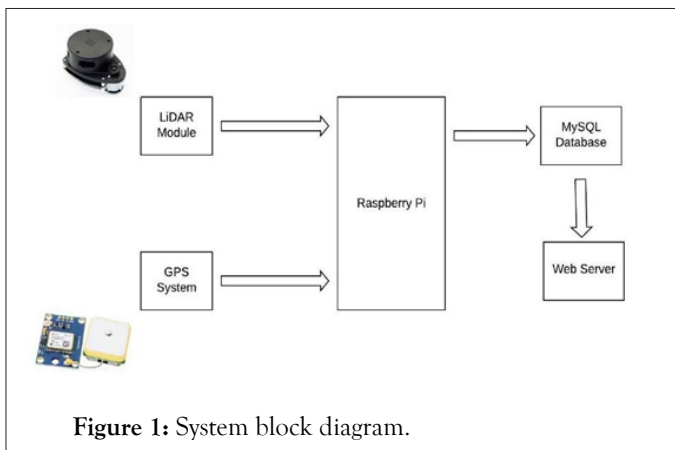


Figure 1: System block diagram.

The LiDAR module and the GPS module are interfaced to the Raspberry Pi. The Raspberry Pi is connected to the internet over Wi-Fi and accesses the database established on cloud through this connection. The LiDAR module scans the road ahead and provides 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 the GPS sensor. Further a cloud database is established to store the pothole data with its location co-ordinates. A web application is deployed which marks the location of potholes on Google maps [4].

2D LiDAR based pothole detection method

For accurate pothole detection using 2D LiDAR four steps are performed including clustering, line segment extraction and generation of data function, gradient of data function.

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 Adaptive Breakpoint Detector (ABD) method which constructs clustering by calculating the threshold value D_{max} . If D_{max} then breakpoints are obtained and these points are handled as one cluster.

Here, the distance between the points p_n and p_{n-1} is calculated using Where, r_{n-1} is the range from the sensor to the point p_{n-1} . The distance resolution of the LiDAR and the worst case incidence angle used to extrapolate the largest allowed distance between successive points. Any current point P_n

outside the threshold circle will be considered a breakpoint. If it meets the condition, 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 the 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 $P(x_1,y_1)$ and $p(x_n,y_n)$ are the first and the last abrupt change points respectively. When pothole exists the width of the pothole (Figure 2) [5].

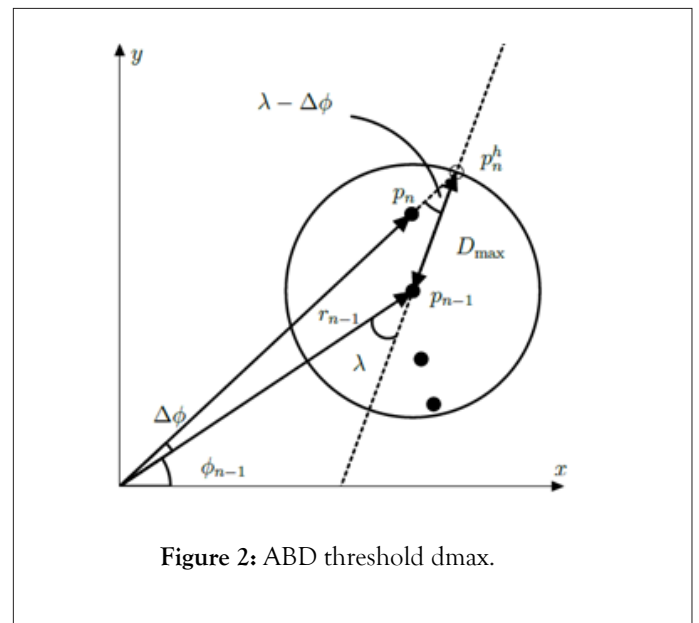


Figure 2: ABD threshold d_{max} .

The GPS subsystem is a crucial part of our project. It is required to obtain the pothole location data. Anytime the algorithm detects a pothole it triggers the GPS program to 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 we make use of \$GPRMC sentence to obtain latitude and longitude information [6].

A database is created that contains pothole data including 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 web server.

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 software in building a database and a server. The LAMP stack contains MySQL which is a database management system which is used to store pothole data [7].

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.

RESULTS

The raw data i.e. distance and angle data of the LiDAR is received through raspberry pi 0 w, and it undergoes clustering and the noisy data gets filtered like points which are very 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 End Point Fit (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 pothole or not, first order differentiation of y is performed. If there is a pothole, the differential waveform of y has abrupt change in the function [8].

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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