Computer Vision based Volume Estimation of Potholes using ZED Stereo Camera

G Sruthi Devi, DVR Mohan, D Srinivasa Reddy, Kiran Vegesna, Gopala Krishna Murthy Nookala

Abstract*: Potholes asphalt state is essential when developing path maintenance platforms. So, potholes and different types of cracks required to be noticed and fixed in due time. Material required to seal the potholes are frequently performed manually, which is labor-exhaustive, time-consuming, slow and inaccurate. Calculating volume of the pothole is challenging because of its asymmetrical shape. The assessment of material required to fill the potholes is one of the significant tasks since shortage of precise amount of material will lead to low-grade compaction while an excess quantity can lead to over banding at the edge and material wastage which need to be transported from a different location. The proposed approach to attain potholes volume in real world footage is relied on stereo vision. NVIDIA GPU and Stereolab's ZED camera hardware have been used to accomplish this task. From visualization of recorded video, depth information of every pixel in each frame is represented by 3D point clouds from 2D image and meshes are generated. Using convex hull algorithm key metrological parameters of pothole is calculated with respect to depth and results are obtained.

Index Terms*: Pavement, Potholes, ZED Camera, Convex hull, Metrology.

I. INTRODUCTION

Pot-holes are irregular-fashioned overtures on road which are nearly about 10 inches in penetration and are mainly formed by the repeated and over usage of the road [2]. Potholes occur mainly at times where the blacktop cover of the lane was damaged out due to traffic and the concrete beneath the tar layer is exposed. Once a pothole is created, its penetration can develop even more deep with rain water rushing the course and forming a massive strain on car's suspension and shocks. This uneven road tormented with potholes might lead to inconvenience to drivers and can cause severe property loss and even results in a car accident. Potholes not only pave way to car accidents, but lethal to motorcycle accidents also. While travelling in heavy speed, the effect might breach the tires of the car. Even if drivers notice the pothole in prior, it takes time to react. Sudden turns or sudden brakes may even cause rollover and serious accident. The drivers of two wheeler vehicles might have to face the threat of harm if they come near to a pothole because of lesser weight and also it is difficult to balance the two wheeler vehicles. So, the chance of meeting up with accidents and possibly death is at a very high rate [1].

Motivated from the above reasons, we came to a conclusion to investigate a system that estimates the volume of detected pothole from real footage captured in ZED Stereo camera. The system which was recommended here will get all the details regarding the three dimensions of potholes and govern the depth and volume of the potholes to estimate the extent of asphalt essential to seal them up.

For depicting information about their appearance such as silhouette, size, penetration, area, volume and to spot them several practises have been recommended. Proper care and maintenance is needed to assess the level of pavement distress. Numerous methods such as vibration based detecting; image and video scrutiny, and a technique used on laser was utilised rather than taking measurements manually. Performing manually is labour-intensive, time-consuming, slow and inaccurate.

Measurement based on vehicle vibration is reasonable but it is not proficient for acquiring measurements related to volume. Industrial and Machine vision cameras require proper lighting conditions. Under uniform lighting conditions, the resolutions based on 2D visualization can assess shape of the potholes but cannot attain the precise penetration of potholes. The solutions based on Ultrasonic sensor to calculate the penetration and elevation of the pothole is cost effective but the main drawback is that sensor has to be set up beneath the vehicle and it needs to be passed through pothole to calculate depth properly. Microsoft Kinect® is a motion detection camera which even calculates depth in addition to RGB image, has the disadvantage of its own that it is slower in recording depth maps with large resolution. Perhaps, the aid of ZED stereo camera for this cause is still an innovative idea. Also, it gives improved depth position cloud than Kinect®. Here we implemented a method which provides capacities in three dimensions based on the visualization of the computer from which geometric measures of the potholes were dogged effortlessly. It provides an alternative for 3D analysis and however captures more details than Kinect®. In the analysis of depth, the IR projector radiates a pattern feasible over a particular penetration which is administered by the IR receiver as associated with Kinect® and is generated which is reliable for indoor applications, 3D stereo vision in ZED has advantage that the algorithms are smeared on the two dimensional images which aligns pixels and calculate the better depth point cloud in case of outdoor applications.

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II. LITERATURE REVIEW

Koch [3] calculated potholes tracking based on vision. With the aid of video sequences the system of pothole detection was executed and using a reference texture, obtained texture is compared to detect. Firstly, detection of pothole is done and there after it is tracked using kernel based tracking system. With the assistance of MATLAB, processing of data is performed. This method shows the outcomes for the count of potholes spotted in a video which is recorded.

Qingguang Li [4] studied a 3D scanning based on real time to identify potholes on the path for pavement damage scrutiny which uses 3D transverse scanning techniques which are of great speed and less cost scrutiny.

Yao [5] considered operator of order moment on imageries at outward of the road and planned pothole axes (major and minor) and alignment. Youquan [6] used sensors which capture images and line LED's for pothole detection using 3D projections. With respect to smooth surface, the coherent light emitted by LED contributes diverse effect on pot-holes.

Rajeshwari Madli [7] suggested an economical resolution for detecting the potholes and also for calculating the penetration and elevation using ultrasonic sensors. Information of potholes is kept in database (cloud). To identify the penetration correctly, sensor must be kept beneath the vehicle which needs to pass through the potholes.

S.B.S Murthy [8] solutions based on two dimensional vision cannot attain the precise penetration of potholes. From 2D vision, potholes regions are signified in a square shaped tile matrices and predicted outline of the pot-hole is obtained. Moreover, these solutions are feasible only when lighting environments are unvarying. Salari [9] made use of stereo vision system for the evaluation of asphalt damage. By recreating the road exterior, they targeted to estimate the extent of distress in coming days.

Fan [13] is a latest effort which bank on sub pixel discrepancy approximation on Road surface. To evaluate discrepancy for the imageries attained by a ZED stereo which is off shelf parabolic fits are prepared. The paper reports obtained 0.1 – 3 mm error for measurements close to 0.5 m which makes the proposal worthy.

III. ZED STEREO CAMERA

ZED is a Stereo camera which is used for observing the world in three dimensions and also applied in the fields of Penetration Detecting and Motion Tracing [10]. It takes aid of superior detecting equipment which is utilized for penetration perception. ZED performs much better than Kinect® sensor in case of outdoor applications. Stereo labs ZED depth viewer provides depth in range of 0.5-20m (1.64 to 65 feet) can be extended to 30m in ULTRA mode with an accuracy of 0.4-1mm. Having 32 bits Depth format and Baseline is 120. Depth capt ure can be as high as 100FPS for WVGA video mode. With its ultra-shape six element all-glass dual lenses the angle is 110 wide angles.

IV. EXPERIMENTATION

A ZED Stereo camera is positioned on the moving vehicle for screening the path surface. Having one USB Drive with Drivers and SDK, it can be used for accessing and additional processing of stereo images. ZED is connected to Laptop having NVIDIA GPU with compute capability greater than 3 through Universal Serial Bus port 3.0 and extra power resource is not required for further process. For processing we have used Jetson TX1 board which is CUDA capable. Fig. 1 shows the Experimental setup. The images are taken approximately at 5 to 10m under different driving possibilities. Images obtained from ZED are 4416x1242 pixels in resolution for 2.2k video mode at 15fps or 3840x1080 pixels in resolution for 1080p video at 15fps. For investigation and assessment, pot-hole images were captured around the S.R.K.R College campus and various locations in Bhimavaram during mid afternoon to evening time of the day to capture dataset with variety of screening and lighting conditions. Image acquisition was done using Ubuntu Linux environment. For the processing environment we have used Python.

Fig. 1: Experimental Setup

A. Static Testing

For static testing, we have used known shaped regular defects whose volume is well-known. For static imaging also same experimental setup has been used for experimentation.

B. Dynamic Testing

Pre-recorded videos are required in order to notice the asphalt for conservation consultants and surveying staffs. Fig. 2 shows the Basic Flowchart algorithm. Physically surveying potholes and then imaging them one by one is not possible without stopping the traffic. Recorded video present a good scope and complete coverage extent for reporting a road and it is out of harm's way, and also saves time. Hence, it is the only feasible choice for dynamical testing, that placing a ZED camera in the moving vehicle.

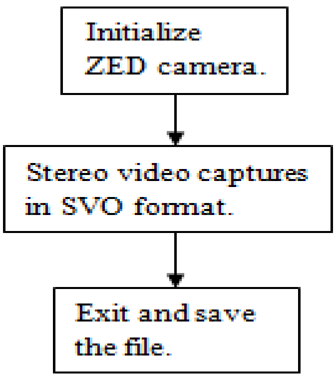


Fig. 2: Basic Flowchart Algorithm

The imaging setup is mounted on a car. Vehicle speed is kept constant at 10 to 25 km per hour. From the recorded video frames of potholes are manually extracted from a pre-recorded video footage. These extracted frames can be recognized automatically, by using different methods which already exist on identification and post processing of potholes [11]

V. METHODOLOGY

The suggested methodology shows a technique to achieve the pot-hole restoration of three dimensional images. In this segment, it designates the recommended algorithm to improve the volume estimation. The severity of the defect information can be known only from its pot-hole's penetration, and its bowl-shaped region above the path exterior. Intensity value in image of penetration gives the utmost deepness of a pot-hole.

The pot-hole's volume in asphalt pavement image gives the assessment for material necessary to seal the pot-holes and cracks. There is a threshold value of 2m, i.e. the video should be captured more than 2m of pixel range. Real world footage videos are recorded in Stereolab's SVO file format. Required pothole images obtained from video frames are extracted making a pause button and selecting the required surface coordinates. By using ZED camera depth is calculated using inbuilt libraries. The attained depth of 3D cloud point is accountable from the origin (0, 0) coordinates. Firstly, the region is segmented which is representing the pothole. Then from depth sensing built-in functions the disparity and dimension parameters are processed to triangulation method function and a three-dimensional view of depth map is generated from the 2D image representing the surface coordinates. Now, 3D cloud points are generated using convex hull algorithm by plotting depth axis (i.e., z-axis) values of each point parallel to x-axis and y-axis coordinates in a plane. Meshes with dissimilar azimuth's and elevation's are generated consequently for image in 3D world points of potholes. The cloud point's are obtained as the total cloud points which is subtracted from the surface cloud points using convex hull algorithm volume is estimated from the pothole.

$$C(P) = C(T) - C(S)$$

Where,
C (P) = Pothole cloud point's.
C (T) = Total cloud point's.
C (S) = Surface cloud point's.
The cloud point's stored information is represented in an image as:

$$Im(x_j, y_j) = z_j \qquad \forall\, j \in PC(P)$$

Where x_j, y_j and z_j are the coordinates of j^{th} element cloud point of a pothole C (P), and Im is the image of penetration in the pothole. To evaluate the pothole's volume the values in depth are calculated using convex hull algorithm. To get the volume accuracy, computing the 3D world points in the pothole using Quickhull method. By using this we build an application for reconstruction of potholes in this real world. Fig. 3 shows the complete reconstruction flow chat algorithm of a pothole for proposed methodology.

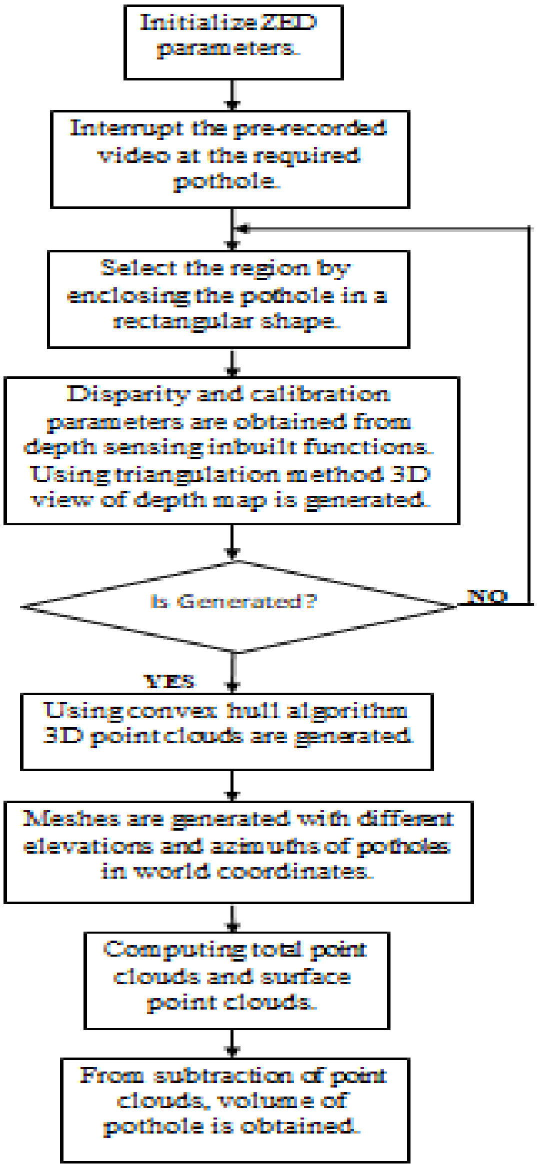
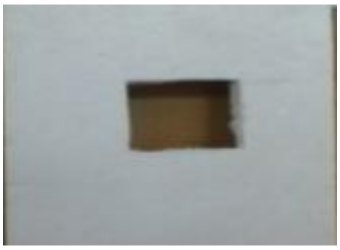


Fig. 3: Proposed methodology for reconstruction of a pothole.

VI. RESULTS AND ANALYSIS

For a static analysis, stereo image captured with ZED setup having a flat surface of a thermocol sheet. Fig. 4 shows the Artificial regular shaped defect created manually and selected coordinates of a defect. From selecting the rectangular area of the required surface 3D view of depth graph is created from the 2D image. The convex hull algorithm is passed to 3D depth view such that 3D cloud points are generated by plotting z-axis. A base surface plain of a sheet is placed at a threshold distance of around 2m.



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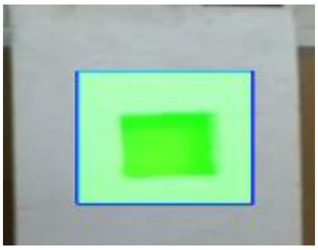

Fig. 4: Artificial regular shaped defect created manually and selected coordinates of defect

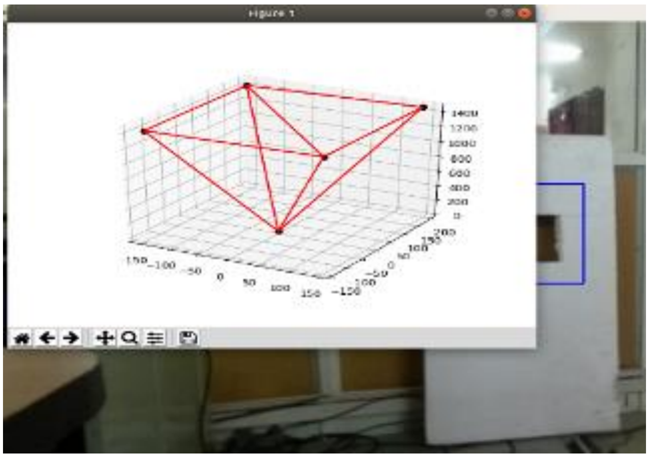

Fig. 5: Depth axis of artificial defect

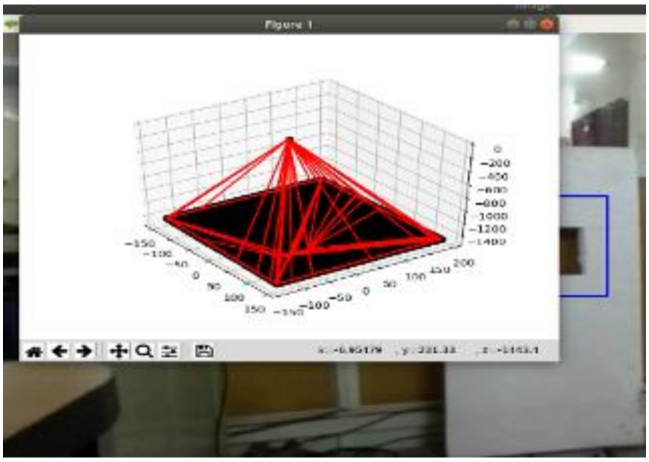

Fig. 6: 3D point clouds of artificial defect.

The accuracy is determined by creating a known shape and volume of a static artificial defect. A stereo image is taken from the apparatus setup with known dejection from an artificial fault sheet. Then, it is processed as outlined in the methodology segment to calculate the volume. The artificial defect is embedded in the sheet as shown in figure 4. Fig. 5 shows the Depth axis of artificial defect and fig. 6 shows the 3D cloud point's of artificial defect which need to be reconstructed to estimate the volume. The calculated volume of the depression error is calculated against the actual volume.

Fig. 7: Images of Potholes A and E

Fig. 7 shows the potholes, recorded and alienated frames which were took from a moving vehicle. Coming back to processing, Fig. 8 and 10 shows the depth axis of 3D plot of potholes A and E respectively using triangulation method.

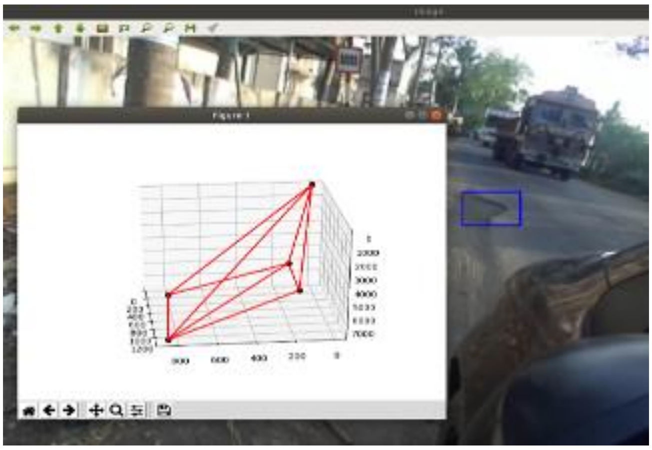

Fig. 8: Depth axis of pothole A

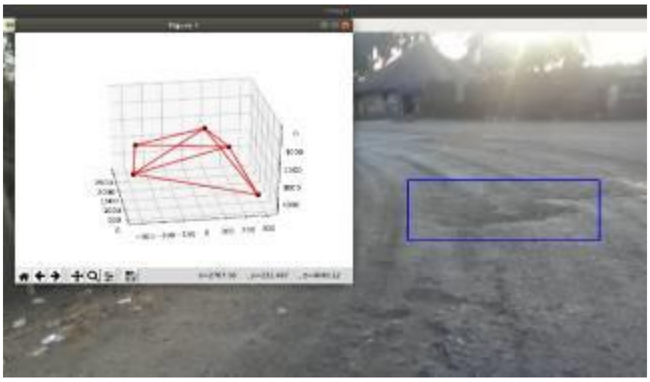

Fig. 10: Depth axis of pothole E

The mesh potholes of 3D reconstructed potholes A and E are shown in fig. 9 and 11 respectively. The potholes are exposed in different angles, where larger penetrations are the portions with higher elevated peak coordinates in plot and meshes. Larger the peak coordinate points, elevates the higher depth in 3D. The x and y coordinates are in real world

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while the z coordinate represents the penetration axis in normalized real world. The world coordinates are in cubic millimeters.

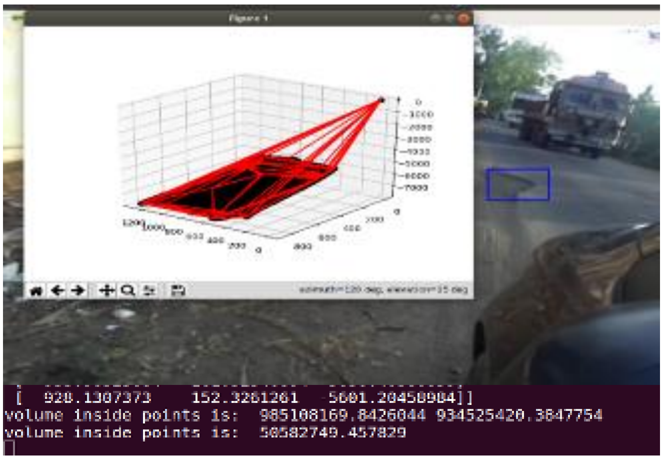


Fig. 9 3D Reconstruction of Pothole A

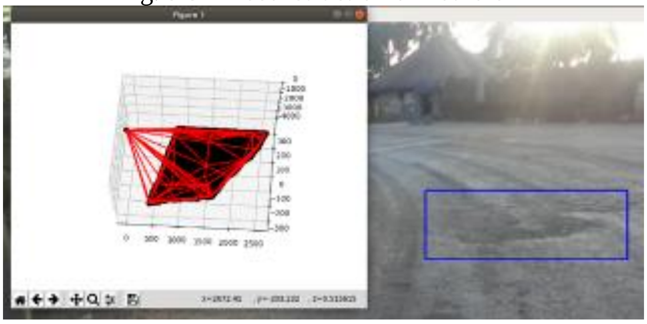


Fig. 11: 3D Reconstruction of Pothole E

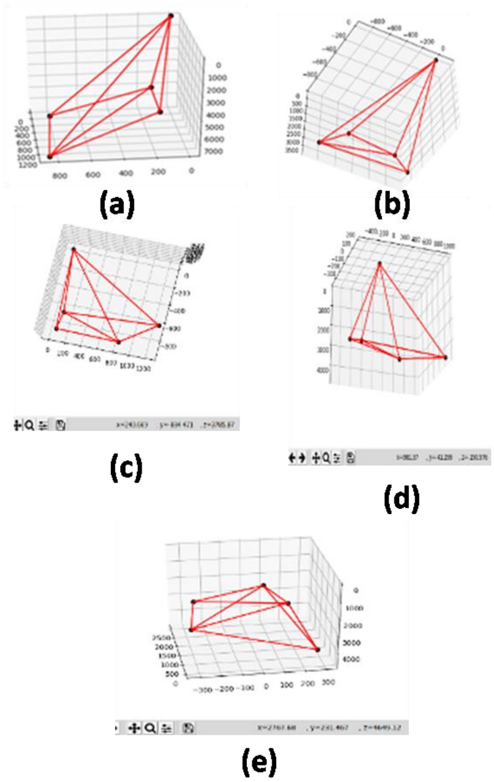
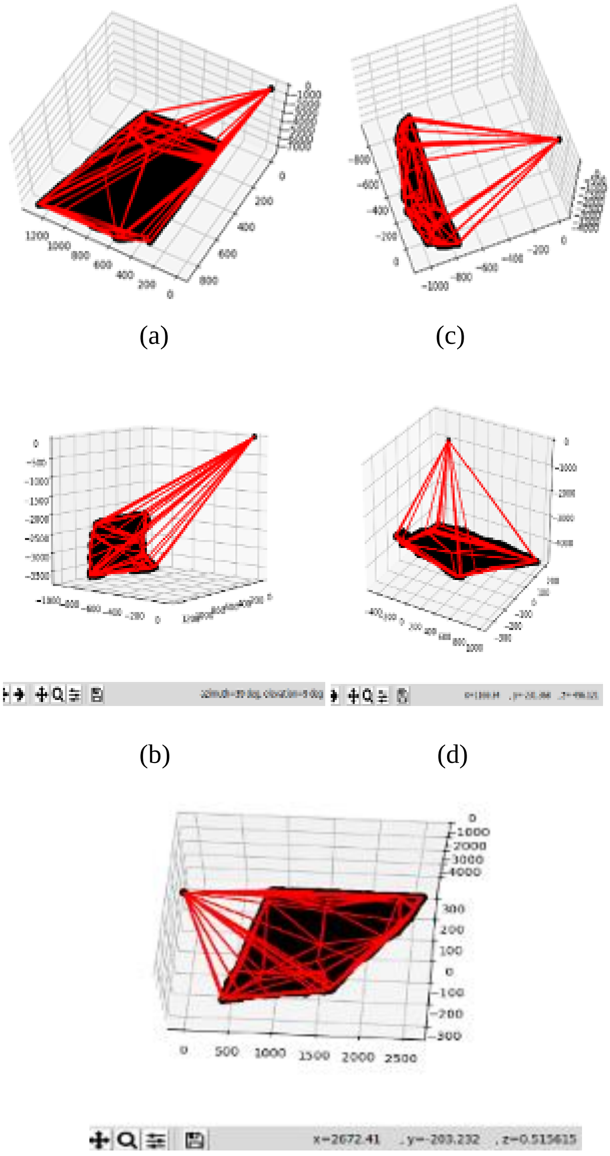


Fig. 12: Graphical Representation of Depth Axis



(e)

Fig. 13 3D cloud points after processing the potholes

Five various peaks of potholes are displayed for analysis and their graphical plots as shown in fig. 12 and different reconstructed 3D cloud point's are generated from 2D graph potholes are shown in fig. 13.

Table I illustrates the experimental estimation by ZED and manually estimated volume's of 5 different potholes. Rajab [12] proposed way for manual measurement has been used. From the images and calculated volume we can say that, when depth is reduced pothole depression will also be reduced. Calculation of volume is obtained by applying the convex hull algorithm. The volume includes surface area roughness also. When the vehicle speed is increased, there are chances of less reconstructed 3D cloud point's are identified; thus volume calculation error will be more. However, it is a fact that when less cloud point's are identified then it occurs in low accuracy which is not because of algorithm fault; image blur is a main reason of problem. This can be rectified by reducing to short exposures results in low intensities.

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TABLE I.: MANUALLY AND EXPERIMENTALLY CALCULATED VOLUME PARAMETERS OF DIFFERENT POTHOLES

Different Potholes	Volume of potholes	
	Manually Calculated (mm^3)	Experimentally Calculated (mm^3)
A	5242	5058
B	6155	5969
C	7408	7246
D	4397	4115
E	8373	8212

When the light cascades, then the sensitivity of an image drops there by approximate shape is recovered in the 3D reconstruction. It is a significant point to note, that all Stereo and computer vision based systems work only under certain controlled lightening conditions. To overcome these effects, we can use high-power light source in low lightening conditions i.e. in the late afternoon and night times.

VII. CONCLUSION AND FUTURE WORK

This thesis demonstrates a capable role for asphalt distress and metrological study of pot-holes in the coming days. In the 3D reconstruction of potholes, metrological parameters can be efficiently attained from the images acquired by ZED. The result of the system testing has been tested by imaging on both the geometries (static and dynamic).

As part of future scope works we consider improvising volumetric measurement in rainy days as potholes are filled with water. Automatically identify the pothole edges such that process will be much more easer. By means of hardware, using artificial lighting potholes can be inspected thoroughly for measurements.

REFERENCES

1. www.pothole.info/the-facts
2. www.seriousaccidents.com/legel-advice/top-causes-of-car-accidents/ "Potholes are a Top Cause Of Auto Accidents"
3. Koch, C., & Brilakis, I. (2011, July), "Improving pothole recognition through vision tracking for automated pavement assessment", In *Proceedings of the 18th EG-ICE Workshop on Intelligent Computing in Engineering* (pp. 6-8).
4. Li, Q., Yao, M., Yao, X., & Xu, B. (2009), "A real-time 3D scanning system for pavement distortion inspection", *Measurement Science and Technology*, *21*(1), 015702.
5. Yao, X., Yao, M., & Xu, B. (2008), "Automated detection and identification of area-based distress in concrete pavements", in *7th international conference on managing pavement assets*.
6. Youquan, H., Jian, W., Hanxing, Q., Zhang, W., & Jianfang, X. (2011, October), "A research of pavement potholes detection based on three-dimensional projection transformation", In *2011 4th International Congress on Image and Signal Processing* (Vol. 4, pp. 1805-1808). IEEE.
7. Madli, R., Hebbar, S., Pattar, P., & Golla, V. (2015), "Automatic detection and notification of potholes and humps on roads to aid drivers", *IEEE sensors journal*, *15*(8), 4313-4318.
8. Murthy, S. B. S., & Varaprasad, G. (2014), "Detection of potholes in autonomous vehicle", *IET Intelligent Transport Systems*, *8*(6), 543-549.
9. Salari, E., Chou, E., & Lynch, J. J. (2012), "Pavement distress evaluation using 3d depth information from stereo vision", (No. MIOH UTC TS43 2012-Final), Michigan Ohio University Transportation Center.
10. [online] Available: www.stereolabs.com/
11. Chang, K. T., Chang, J. R., & Liu, J. K. (2005, July), "Detection of pavement distresses using 3D laser scanning technology", In *Proceedings of the 2005 ASCE international conference on computing in civil engineering* (pp. 12-15).
12. Rajab, M. I., Alawi, M. H., & Saif, M. A. (2008), "Application of image processing to measure road distresses", *WSEAS Transactions on Information Science & Applications*, *5*(1), 1-7.
13. Fan, R., Ai, X., & Dahnoun, N. (2018), "Road surface 3D reconstruction based on dense subpixel disparity map estimation", *IEEE Transactions on Image Processing*, *27*(6), 3025-3035.
14. Koch, C., & Brilakis, I. (2011), "Pothole detection in asphalt pavement images", *Advanced Engineering Informatics*, *25*(3), 507-515.

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