Detection of Pothole in Roads Using ML

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Abstract- In this report, I have proposed the idea of developing a software which detects the potholes in the Indian roads with the additional features of how bad the road is. It will be very helpful for every citizen in any country specially in India where we know that the roads in the middle of the city , or in the villages are not good and rough roads are a great havoc to everyone specially in the metro cities in the peak hours of office , college.

1.0 Problem Statement-

For a nation to offer countrywide commuting options, roads are a need for transportation. Road infrastructure makes it possible to link people and move commodities, which improves the availability of employment, business possibilities, and the healthcare system nationwide. Potholes are signs of a badly maintained road, which could suggest a structural problem underneath. In addition to making for an uncomfortable ride, a vehicle's collision with a pothole can result in costly repairs to the wheels, tyres, and suspension system of the vehicle.Potholes should be dealt with on a priority basis to minimize their contribution towards unfortunate scenarios. According to the prediction made by WHO road accidents will become the fifth leading cause of death in 2030. The significance of potholes created conspicuous interest for the researchers of the civil community.
I hope to create a service that can provide a solution with insights into how to solve this and show the data accurately in the first few months for free and then customers will be bound to subscribe for a long time if the data is correct.

2.0 Customer Needs Assessment-

The normal commuters,businessman , doctors who drive to workplace daily using their own vehicles to travel to their workplace and back to their home face a really worst issue while travelling along the roads , ie, bad roads or potholes in the roads especially the Indian roads which gets worst with huge loads of trucks , vehicles stuck in a jam to make the situation more critical. It is also very difficult for the emergency services to face the same issue which can cause life risks to the people.Therefore by developing a software a huge demand can be gained and thus profit can be earned with adding more features in the future.

3.0 Target Specification-

The proposed system/service will be beneficial for everyone who travel along the roads for their day-to-day work so that they become alert whenever there is a pothole or a rough road which will both prevent from an accident.Also adding few more features such as conditions of road in the monsoon- whether it is flooded or not and many such will bring more credibility in the services which will attract more customers.

4.0 External Search-

I took help from few websites for for analyzing the need of this system and also to find how this system is used across the globe currently.Few of the websites are mentioned below:

1. The pothole crisis- An inconspicuous issue
2. Accidents due to the potholes
3. A modern pothole detection technique using deep learning
4. Pothole Detection DataSets-Kaggle
5. Pothole Detection Image Datasets-Github

5.0 Benchmarking Alternate Products-

The fundamental level of identification of potholes, which identifies the detection of potholes, is being worked on by a small number of startups like RoadMetrics, large tech companies like Google, and a small number of sensors. However, this concept will also function to detect uneven roads in addition to detecting potholes.

6.0 Applicable Patents-

1. Pothole Detection System Patented by Google-
   Recently, Google was granted a patent for a system that uses GPS and on-board sensors to evaluate the state of the roads. In essence, as soon as a car travels over a pothole, the automobile's sensors detect the flaw in the road. These sensors send signals to a vehicle head unit, which evaluates the condition of the road. After that, a mobile network transmits this data to a centralised server, enabling Google to compile a database of damaged roads. This can then affect driving instructions on mapping software so that other drivers can steer clear of potholes well in advance.
2. Pothole Detection Using Transfer Learning-
   Tensor Flow has created a system that predicts potholes using Transfer learning and Inception v3 approach. This technology assists in locating potholes in the road, alerts drivers to them while they are driving, and uploads the information to a server so that the relevant authority can take immediate remedial action. The project's goal is to build and create a mobile application that can locate potholes.

7.0 Applicable Regulations-

The few regulators of India who regulates the Transport and Motor Industries in India are as follows:

1. Bureau Of Indian Standards(BIS) -Acts of Parliament was passed on November 26, 1986, and April 1, 1987, renaming the previous Indian Standards Institution(ISI) as the Bureau of Indian Standards (BIS) with expansion of its authority . The BIS handles a variety of tasks, including developing standards of national importance and bringing national standards into compliance with international norms, certifying imported goods, managing management system certification (IS/ISO), creating awareness campaigns, and providing training services..

2. Ministry of Road Transportation and Highways(MORTH)- The Ministry of Road Transport and Highways (MoRTH) is responsible for developing, implementing, and conducting research related to road transportation and highways in India. Its goal is to make Indian road transportation more effective. It consists of two wings, each with distinct duties:
    - Roads Wing:
        - ❖ The development and maintenance of national highways
        - ❖ Providing technical and financial support to states for road development projects
        - ❖ The development of standard specifications and the collection of information for India's roads and bridges
    - Transport Wing:
        - ❖ The taxation of motor vehicles
        - ❖ Enforcement of mandatory insurance of motor vehicles
        - ❖ The administration of government acts relating to road transport, such as the Motor Vehicles Act of 1988
        - ❖ The promotion of road safety

3. Legislative Background-In India, the legal foundation for emissions, air quality, and fuel standards is based on several laws,few of which are mentioned below:
    - State governments have the authority to make sure that all necessary commodities, including petroleum products, are widely accessible to the general public and adhere to government criteria under the Essential Commodities Act of 1955. In addition, it asks for people who break the law to pay penalties, serve up to a year in jail, and lose their ability to conduct business.
    - The Air (Prevention and Control of Pollution) Act, 1981 gives SPCBs the right to prohibit the production or burning of any fuel that is determined to lead to air pollution.
    - The Data Protection Act of 2018 is the regulation that mandates that personal data be kept on Indian soil. Important personal information must be kept only on domestic soil. The Bill establishes a national Data Protection Authority (DPA) to oversee and control data fiduciaries.

- The Environment (Protection) Act of 1986 does not address fuels expressly, but it does give the federal and state governments the authority to control actions that potentially harm the environment, which could include burning fossil fuels.
- Vehicle emission regulations were created by the Motor Vehicles Act of 1988, which also gave the national and state governments the power to further regulate and enforce them.

8.0 Applicable Constraints-

There are few challenges which needs to be faced before developing the actual solution, few of them are as below:

1. Collection of data and mapping them as India has a vast network of roads.
2. Continuous data collection accurately and properly updating them regularly.
3. Convincing the users to use the application/software developed.
4. Lack of technical knowledge to many users especially along the village side.
5. General Awareness among the effectiveness of the app
6. Capital needed is also huge for ensuring the collection of data , developing and training the software.

9.0 Business Model-

The above way of pothole detection, which is extremely expensive in terms of both the service model and the sensor model, has only been employed by major organisations. However, by using this method, all customers may use this service at a much reduced cost. Because of its reliable performance, it may also be employed at some organisational levels like hospitals and nursing homes. As a result, there is a good probability that the service we give will be a terrific business opportunity.

10.0 Concept Generation-

In India in 2021 alone, as many as 4 lakh incidents were only reported officially and unofficially it is much more than that. Out of these accidents around 20-30% accidents are caused due to bad roads and potholes which took the lives of many people and seriously injured many.

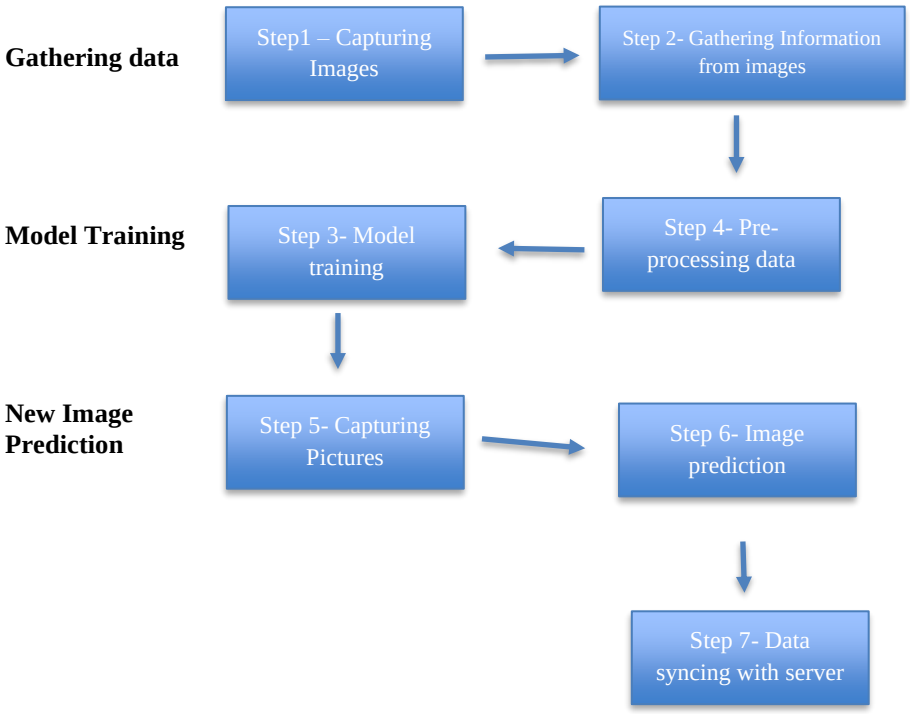
11.0 Concept Development-

The idea development phase involves building a technological prototype using fewer data sets and analysing its potential market effect, particularly with hospitals and nursing homes for the system's use. The concept's aim was to create the software in a more efficient and affordable manner so that anybody could use it.

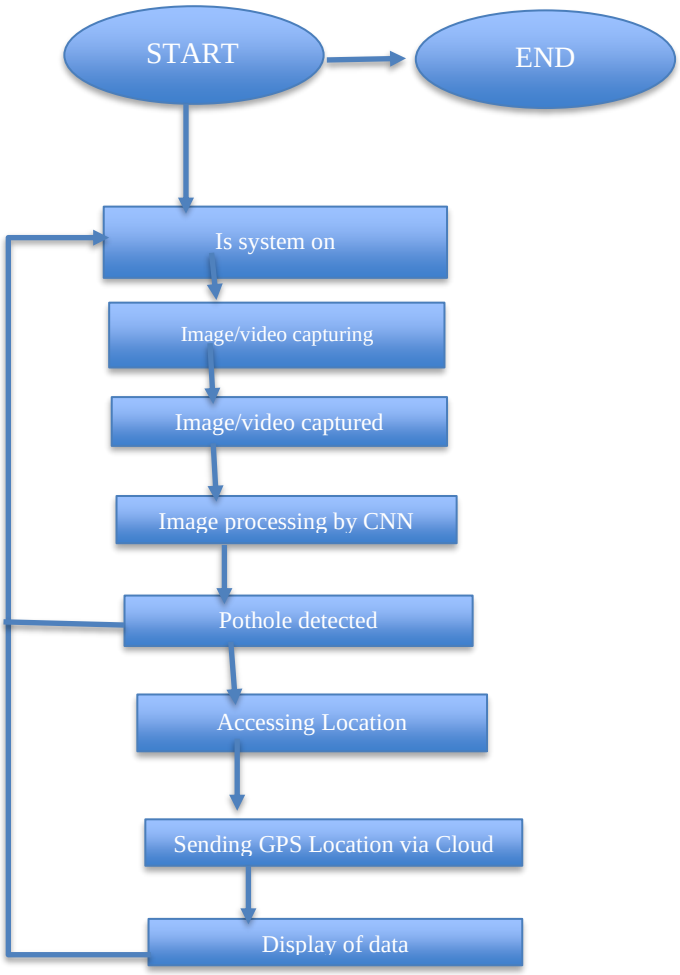
12.0 Final Product Prototype with Schematic Diagram-

There were several network architectures employed for this project. Numerous network designs were explored to determine which one performed the best with the given dataset. The network designs included YOLOv3 with the Inception v2 backbone, Faster RCNN (Region-based CNN), and SSD (Single Shot Detection) (You Only Look Once). This section discusses the justification for selecting YOLOv3 as the network for this project's application. The results indicated that although being more accurate than SSD, Faster R-CNN was inappropriate for real-time detection because to its extraordinarily lengthy inference time.
Further research revealed that videos, which are normally produced at a speed of at least 24 frames per second, would probably not be able to keep up with the Faster R-CNN. Since faster R-CNN is a regional technique with two phases—proposing regions and processing them—it is quite useless for real-time detection.

The overall process to be followed to achieve the desired results is as shown in the figure below:



The overall system will work like this as shown below:



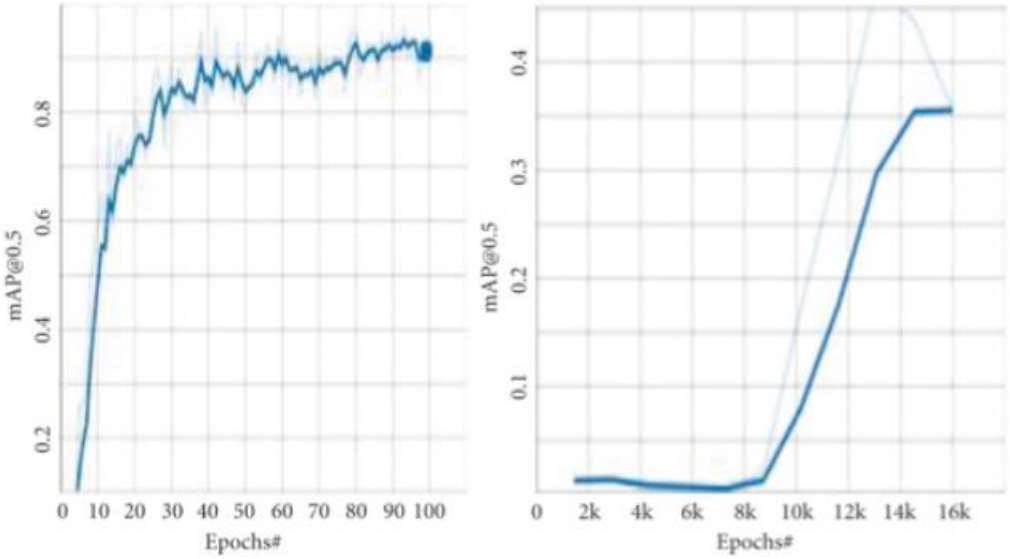
13.0 Product Details-

The suggested method is to use an OAK-D camera with a Raspberry Pi for real-time implementation. OAK-D requires a host computer with a USB port to connect it in in order to function computationally; for this, both windows and raspbian are utilised. To get our model working, the next step is to install DepthAI, a computer vision library made available by Luxonis. Once the DepthAI needs have been installed, the custom model on OAK-D may be used. OAK-D sensor was chosen as a result of its capabilities as a SpatialAI tool, which include the ability to run complicated neural networks, provide depth via its left and right stereo cameras, and identify objects using the 4K RGB centre camera.
The Myriad X VPU hardware in Luxonis OAK-D is not optimised to support the darknet framework. The custom model must be converted from darknet YOLO weights to OpenVino format in order to be used with OAK-D for real-time detection. Since it lacks a straightforward translation technique for darknet weights, it first needed to be converted to TensorFlow.pb weights before being converted to OpenVino. The.blob file has to be distributed on the OAK-

D kit after conversion. The conversion of the YOLOv5 is best done for OAK-D deployment. The ONNX framework,.xml and.bin file, and the.blob file, in that order, get pt PyTorch weights. By converting Tensorflow.pb to.xml and.bin to OpenVino IR representation, which is.blob file, SSD-Mobilenetv2 weights are also transformed to OpenVino.blob file.
Convolutional neural networks are used by the deep learning algorithm YOLO to recognize objects. A 1 x 1 kernel is used to create the output of YOLO when it is applied to a feature map. For YOLOv3, feature maps of three different sizes are applied using 1 x 1 detection kernels at three separate points in the network. The number of bounding boxes that a cell on the feature map can predict is B, and the shape of the detection kernel is 1 x 1 x (B x (5 + C). The number "5" stands for one object confidence and four bounding box characteristics. The letters"C" stand for the number of courses.

The Darknet deep learning framework developed by Joseph Redmon was utilised for this project.The YOLOv3 annotated files must be in text format, represent a single bounding box in the picture, and contain the information listed below. The object-class-id, the first field, is a number that denotes the object's class. This number is between 0 and (number of classes-1). This value is always set to zero because there is only one class involved in this project. The x and y coordinates of the center of the bounding box, multiplied by the picture width and height, are the second and third fields, center-x and center-y, respectively. The bounding box's width and height, which are the fourth and fifth fields, are calculated by dividing them by the image's width and height.
The YOLOv3 annotated files are required to be in a text file format.. The ".txt" file comprises of rows which represent a single bounding box in the image and contains the following information about the bounding box: <object-class-id> <centre-x> <centre-y> <width> <height> The first field, object-class-id, is an integer that represents the class of the object. This number ranges from 0 to (number of classes-1). Since this project only comprises one class, this number is always set at 0. The second and third field, centre-x and centre-y are the x and y co-ordinates of the centre of the bounding box divided by the image width and height. The fourth and fifth field, width and height are the width and height of the bounding box divided by the image width and height.
It was essential to send the GPS coordinate of the discovered pothole to a cloud server after the YOLOv3 algorithm was able to detect potholes on the road with accuracy. For this project, the GlobalSat BU-353-S4 receiver was employed. A highly sensitive, low-power chipset in an incredibly small package makes up this receiver. It performs well in urban canyons and thick vegetation thanks to a SiRF Star IV GPS chipset. A magnet incorporated within the gadget allows it to attach to the top of a car. Due to its ability to tolerate both cold and extremely heated temperatures, elemental exposure is not a problem.
To let other drivers know where the potholes are, the position of the detected one has to be transmitted to a cloud server. Ubidots STEM was the cloud server used for this project. Ubidots is a firm with two platforms: Ubidots and Ubidots STEM. IoT may be integrated into business and research due to the Ubidots platform for data analytics and visualisation. It is possible to turn sensor data into information that may be used to make business choices and to communicate with machines.
This is the main idea by which this project will work, the data sources being collected mainly manually which will primarily need some prior investment or grants for developing this project along with a team of engineers working on the technical field,IoT segment and another team who will be collecting data manually to avoid noise in the data.

Validation accuracy curve of YOLOv5 vs SSDMobileNet-v2



14.0 Code Validation on Small Scale-

The OpenCV AI Kit (OAK-D) has been put in the middle of the dashboard of the car for real-time testing in order to collect as much of the road as is practical for better evaluation. However, the experiment's average speed remains at 65 km/h. OAK-D used Raspberry Pi as its host computer. With a high FPS of 31.76, the Tiny-Yolov4 can identify potholes at a distance of 10 metres from the dashboard.
In comparison to YOLOv2, YOLOv3, and YOLOv4, Tiny-YOLOv4 is thought to be the best model to use for real-time pothole detecting systems since it has the greatest detection accuracy. As it only detects when the confidence level is 30% or less having false and no detection, SSD-Mobilenetv2 has demonstrated poor performance. In real-time inference, YOLOv5 misses a lot of potholes and has an 18.25 FPS. For real-time pothole detecting systems with high FPS but low accuracy, it is beneficial.
The YOLOv3 architecture does not perform well for real-time applications since the inference speed was the quickest of the three tested designs, producing the best results for this project's application. Of the three models, the Faster R-CNN network turned out to be the most accurate. Due to the different sizes of the potholes, SSD fared the poorest in terms of accuracy. Next, these GPS coordinates were sent to a cloud server so they could be saved and subsequently shown on a map.

Simple exploratory data analysis (EDA) could include summarising the IoT technology , Ubidots system, GlobalSat BU-353-S4 receive,etc.

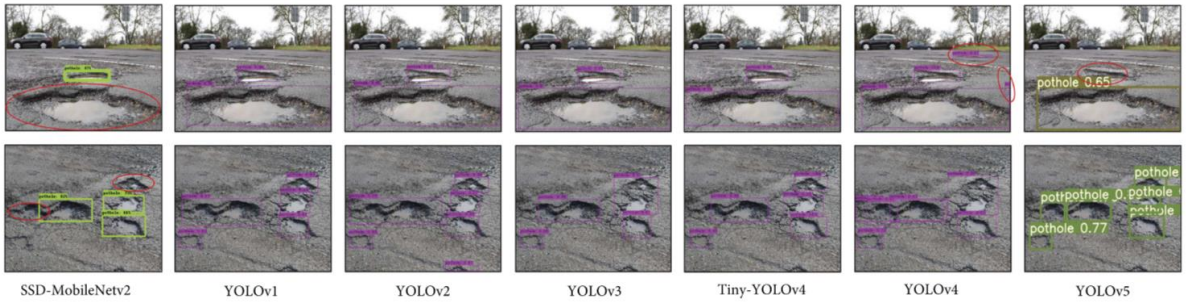
Mean average precision is a metric utilised to evaluate object detectors. It is the average of the average precision.To comprehend MAP, it is necessary to define the terms ‘precision’, ‘recall’ and ‘IoU’(Intersection over Union).Recall can be defined as the percentage of the total relevant results that is classified correctly by the algorithm.IoU can can be defined as the ratio of the area of intersection and area of union of the ground truth and predicted bounding boxes.The confidence score can be defined as the probability that an anchor box contains an object. The confidence is predicted by a classifier. Both the IoU and confidence allows one to determine

whether a predicted box is a true positive, false positive or false negative. A threshold value of 0.5 is predefined for the IoU . A detection is considered a true positive (TP) only if the following three conditions are met:

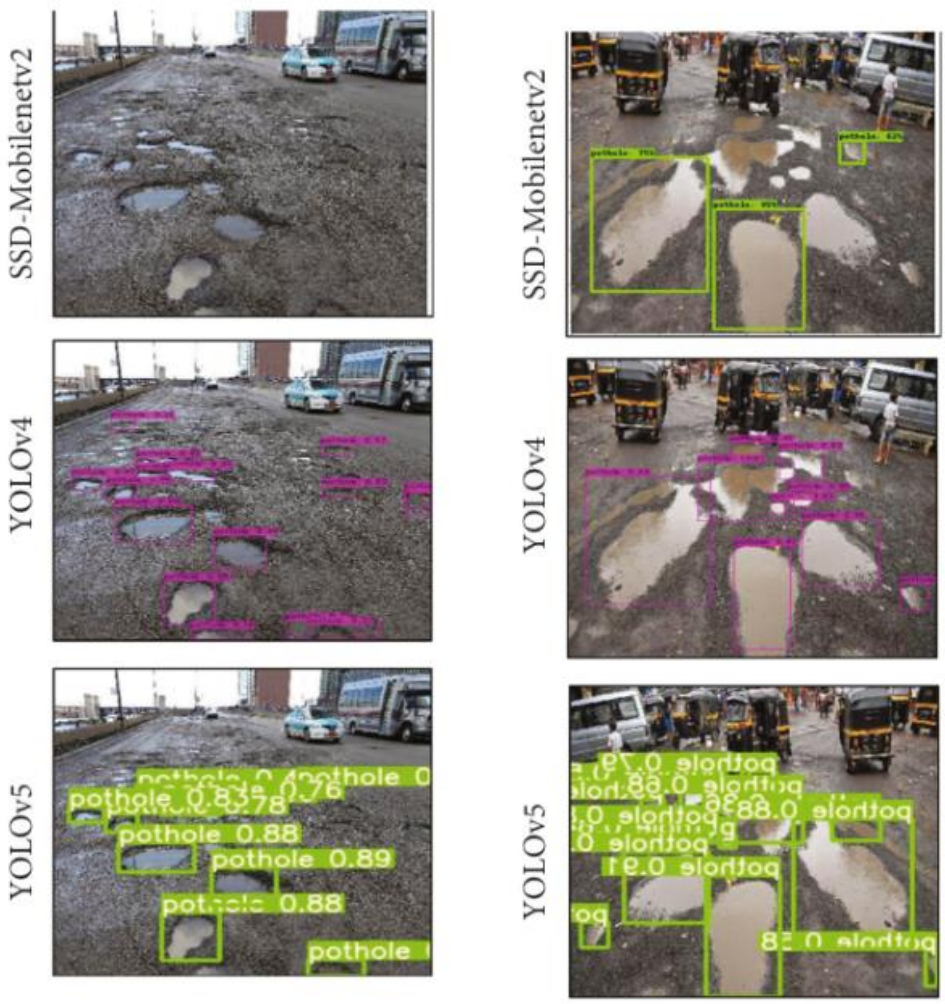
- Confidence score > threshold
- The predicted class matches the class of a ground truth
- The predicted bounding box IoU (e.g. 0.5) is greater than the threshold of the ground-truth

If the above conditions are not met, the prediction is considered a false positive. When the confidence score of a detection that is supposed to detect a ground truth is lower than the threshold it is considered a false negative. When the confidence score of a detection that is not supposed to detect anything is lower than the threshold, it is considered a true negative.These data can be helpful to show how much the data is correct and whether the system needs to be trained more for better accuracy.

Pictures showing prediction by YOLO family and SSD MobileNetv2



Pictures showing prediction by SSD MobileNetv2 , YOLOv4 and YOLOV5



Pictures showing Pothole identification in real time with the Raspberry Pi and OAK-D

15.0 Conclusion-

The above-mentioned theory is confirmed and met because the entire system was able to detect a pothole, determine the detected pothole GPS coordinates and save these to a cloud server. However, a number of enhancements can be made to the existing solution. Such improvements include increasing the dataset size which would include more data visualisation , good investment backup with a good technology and field engineers to become successful in the development of a profitable company which would work first freely for a limited time for a user and then the user needs to pay for continuation of the services on gaining both the user trust and the user experience.