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Full Paper Presentation on

PID-235

Road Surface Analysis and Potholes Detection

L&T Technology Services

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Automatic perception of road surface and potholes detection

Concept / Scope of solution

- To develop a system which can predict potholes/manholes .
- To automatically analyze and classify different road surfaces.
- To make the system learn the current terrain and predict the imminent potholes.
- To provide terrain description and safe navigation.
- To ensure road safety .

Pros and Challenges of the solution

Pros :

- It would enable the drivers to make informed decisions while driving, avoiding the irregular road surface/potholes .
- It would lead to increase in fuel efficiency and longevity of the tires.
- It would lead to significant decrease in road congestion.

Challenges :

- To make the driver aware of these irregularities in advance instead at that exact moment.
- Prediction of the potholes is difficult if the vehicle is moving at high speeds.

Detailed Description

- We will combine the data from two sources:
  1. LIDAR (Light Detection and Ranging) sensors : It is a remote sensing technology that measures the distance by illuminating a target (potholes/manholes) with a laser.
  2. Microsoft Kinect/Depth Sensor : An infrared projector and a monochrome CMOS sensor work together to see the frontal view of the road in 3D regardless of the lighting conditions.
- Input from both of these sensors would be processed with edge detection and gradient image processing techniques, which give edges, and gradients along horizontal and vertical directions, respectively. The resultant feature vectors, obtained from these techniques, will be fed to a **PCA (Principal Component Analysis)** to reduce the dimension of feature space.
- The final feature vectors would be input to **classification machine learning algorithm (kNN , SVM)** which would notify whether we should continue moving in the same direction or change lanes.

Technology/Background

- **Open CV**
  - Prewitt/Sobel Gradient Detection Algorithms
  - Sobel/Canny Edge detection Algorithms
- MATLAB
  - Principal Component Analysis Algorithm (PCA)
  - K-Nearest Neighbor(kNN), Support Vector Machines(SVM) classification algorithms

Development Procedure/Methodology

- Capture training data of four classes of roads i.e. with/without potholes and with/without irregularities on road surfaces using LIDAR and Kinect Depth Sensors.
- Divide the collected dataset as follows: 60% as training data, 20% as cross validation data and 20 % as testing data.
- Apply Gaussian Blur to input images to perform smoothening of the image and filter out the noise.
- Convolve the input with the sharpening kernel $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$ to sharpen the edges in the input.
- Extract out the feature vectors, from the output of pre-processing techniques, using Gradient and Edge Detection algorithms.
- Employ Principal Component Analysis(PCA) to reduce the dimension space of the feature set extracted.

Development Procedure/Methodology

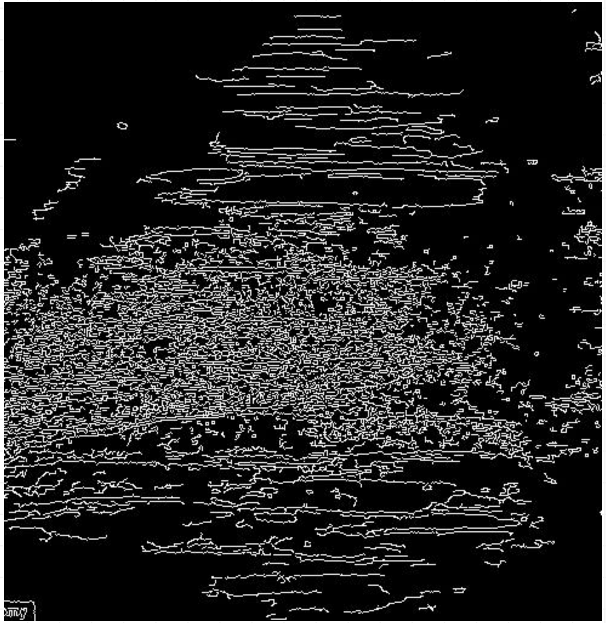
- Train the classification model and estimate the model parameters using k-Nearest Neighbor (kNN) or Support Vector Machines(SVM) classification algorithms.
- Validate the model's accuracy by calculating F1-score statistic.

$$F_1 = 2 \cdot \frac{1}{\frac{1}{\mathrm{recall}} + \frac{1}{\mathrm{precision}}} = 2 \cdot \frac{\mathrm{precision} \cdot \mathrm{recall}}{\mathrm{precision} + \mathrm{recall}}$$

where Precision measures the positive predictive value and Recall measures the sensitivity in the data.

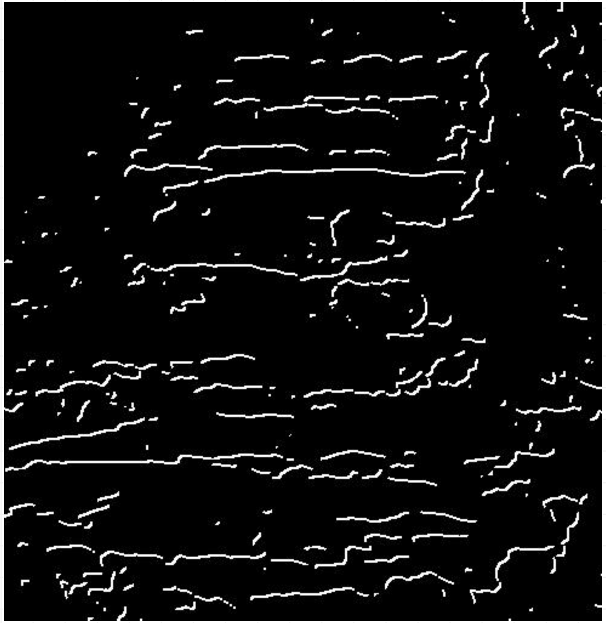
- Predict using the above built model whether or not to stay in the same lane and store these results on the cloud server, for future references.

Implementation and prototype / POC



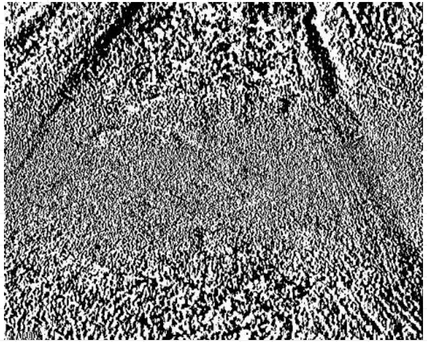
MATLAB : Gradient

Original Image

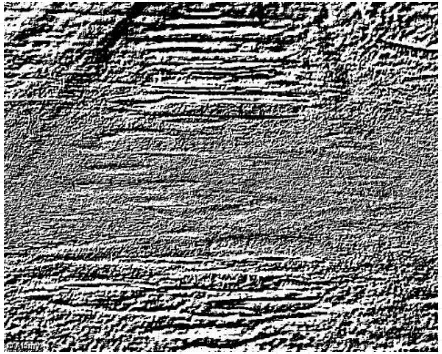


OPEN CV : Adding horizontal and vertical Gradients

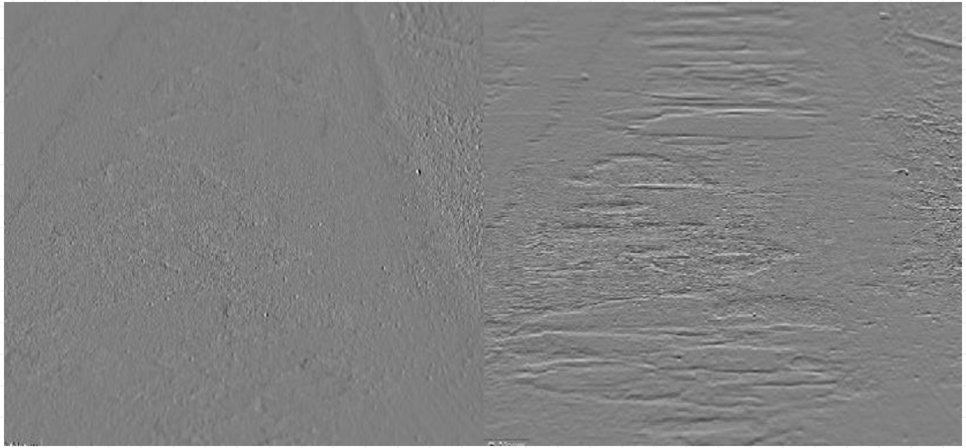
Implementation and prototype / POC


Gradient along Y axis

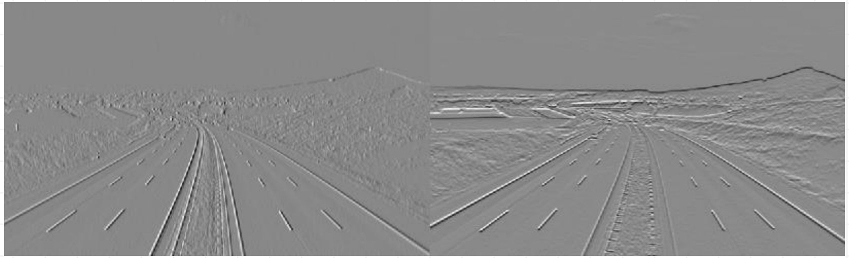
Original Image


Gradient along X axis


Gradient Magnitutde


Directional Gradients, Gx and Gy

Gradient Magnitude

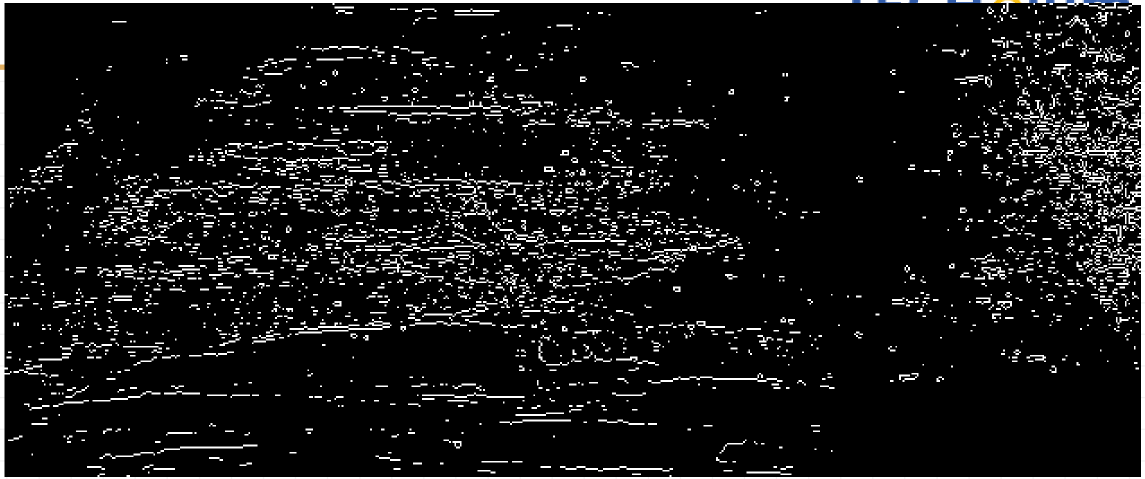


Directional Gradients, Gx and Gy

Original image

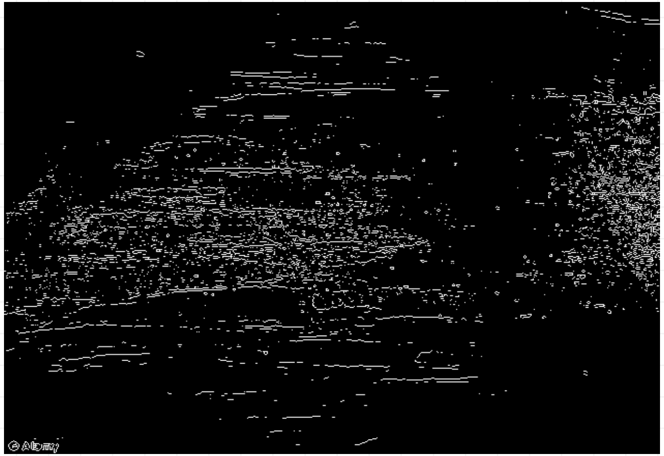
Gradient along X axis

Gradient along Y axis



Canny Edge Detection

Implementation and prototype / POC



Sobel Edge Detection

PID No.

Implementation and prototype / POC

Sobel Edge Detection

Canny Edge Detection

VALIDATION-

- Cross-Validation data is used to predict whether the cross validating data is fitting the model trained, properly.
- The goal of cross validation is to give an insight on how the model will generalize to

an independent dataset/an unknown dataset.

- Note that we have selected 20% of the dataset as cross validation data.

TESTING-

- A **test set** is a set of data used to assess the strength and utility of a predictive relationship.
- We have selected 20% of the dataset as test data set.
- **Mean** F Score. The F1 score, commonly used in information retrieval,

measures accuracy using the statistics precision p and recall r. **True Positives** are denoted by **tp** , **False Positives** are denoted by **fp** and **False Negatives** are denoted by **fn** .

$$\text{Precision} = \frac{tp}{tp + fp}$$

$$\text{Recall} = \frac{tp}{tp + fn}$$

ANALYSIS-

- **Analysis of variance** (**ANOVA**) is a collection of statistical models used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation.
- We have used ANOVA to analyze if the top directions with maximum variance, predicted with PCA, are not redundant.

Cost /benefits

COMPONENTS	COST IN INR	COST IN USD
OPENCV (WINDOWS/LINUX/MAC-OS)	Open Source	Open Source
MATLAB	1,45,000	2000
LIDAR MODULE	12,500	150
KINECT DEPTH SENSOR	10,440	150

TOTAL DEVELOPMENT TIME- 4-6 Months

COST PER MODULE - 400 USD

Results and potential Business Impact for L&T TS

L&T IDPL -Bridges and Road Infrastructure

- It would be easier to detect irregular road surfaces/potholes which would cut down the time required to repair and maintain the infrastructure.

LNTECC Smart Infrastructure

- Tracking the infrastructure would be easier, which would contribute towards the idea of “Smart Cities” and “Smart Infrastructure”.

L&T Construction Business opportunities

- Based on the feedback provided by the drivers, the process of road construction can be efficiently managed.

Conclusion

- The proposed system would certainly bring down the number of road hazards due to unattended potholes/manholes on roads.
- Significant increase in the life of the automobile can be expected.
- It would bring down the maintenance expenses of the vehicles.
- The problem of traffic affected by the roads in bad condition could be avoided.
- The system could be successfully integrated with **BHUVAN** Maps/**GOOGLE** Maps to guide the drivers.
- Additionally, it would lead to less consumption of fuel by automobiles.

References

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That's all Folks!

THANK YOU

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