Estimation of Road roughness Using Image Processing and Machine Learning Techniques

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Abstract

In today's world, Advanced driving assistance systems and self-driven cars inland transports are dramatically in public demand. It is mandatory to detect the road condition for these types of automatic vehicles. With the number of self-driving cars increasing every day, we can't build roads with the same speed to accommodate them. So, we have to build an alternative solution for the same. A software with a road condition detection system can deal with this problem. A combination of machine learning and image processing can be a landmark solution that can predict the roughness of the road. Here we can compared the machine learning models like linear regression, k-nearest neighbor, support vector machine, random forest, naive Bayes, and multi-layer perceptron neural network. This model gives the ability to recognize the situation from its surrounding by enabling continuous monitoring of a wide range of road networks. The result demonstrates the methods that accurately predict road roughness.

Introduction

Driving is a risky job, safety and security are the problems in the automotive field. As automotive industries are more active towards the self-driving car the demand for such an effective system increases. The motivation behind this system is to secure the passengers from the accident. By controlling the speed of a car through this predictive system. There are various technologies available in the market. For example, leaser, LID, radar, depth sensor, etc. but camera is a cost-effective one.

The International roughness Index(IRI) is a common index worldwide for characterizing longitudinal road roughness and managing road system. This measures surface performance and ride quality. In recent times, many new concepts have been proposed to deal with some of the limitations of standard road condition monitoring methodologies. The vehicle vibrations and the road profile in combination have traditionally been investigated utilizing dynamic response models. But, there are some difficulties associated with the practical implementation of such a methodology. For example, determination of system parameters, model formulation, model inversion, and sensitivity to change in system parameters in response to time.
For all those reasons, in this paper, we are discussing road roughness estimation using a machine learning model. Which don't require prior knowledge of vehicle parameters. Using well-controlled data under known conditions the network was trained and evaluated on simulated artificial generated road profiles (1). The comparison between the performance of multi-layer perception, support vector regression, and random forests with SVR gives the best performance (2). The IRI prediction methodologies based on a half-vehicle model simulation of car dynamic response is measured road profile and realistic driving velocity profiles were already proposed in (3).
They explain the constitutional neural network (CNN) model with represented inputs of the 2D image. The performance under different combinations of cars, inputs, and driving velocity and find out that RMSE errors of 0.5- 0.6 m km. IRI prediction through a random forest regression model along with road distress, traffic, climate, and other structural parameters was proposed (4). Although these methodologies show excellence, they are basically on smartphone measurements, without a wider calibrated use in simulated settings. Hence the purpose of this study is to find out the machine learning models that predict realistically. By using the car recorded data at a different speed. The result provide by this study give confidence in proposed methodologies and demonstrate the technology that is suited to meet future pavement condition evaluation needs.

Background Study

A. OpenCV computer vision. Applications of computer vision are already in use. As a car can detect traffic signs and control the vehicle, face detection, etc. Still, there is a lot of scopes where a human can understand the situation, yet the computer struggles with it. Many limitations still need to conquer to achieve human understanding. Some of them are due to the hardware platforms upon which computer vision would run. To deal with this, an open-source computer vision project was introduced. This allows us to explore the results of computer vision while we can improve the underlining implementation. With the collaboration of Intel and Computer vision researchers, The first version was publicly released in 2006 (2) but in 1999 it was initiated by Intel. Now, openCV2 contains different modules more than 2500 algorithms that increase every day.

B. Image Processing Techniques. To improve the raw image from camera or sensors this technique is used on space proves, vehicles or pictures were taken for any application (5). Though there are two domains in this analog and digital but concentration on this work related to digital image processing. Image transformation like scaling, rotation translation images to different positions are coming under the geometric transformation technique. Image filtering and bluing are other ways of image processing. After Image processing enhancement or image segmentation like threshold can have more noises and imperfections, morphological operations help to reduce this imperfection. There are many techniques for image processing here we are discussing a few related to this study.

C. Conversion of Color spaces. To store the image there is various color space. RGB is the most useful color space. The most popular color spaces are described below.

Gray-scale intensify the information of the image. The basis on the intensity of the image there is 256 distinct shades of gray. Grayscale images have faster processes and contain the needed information to output. This is because image processing operations do not need full-color information. A 2D array is used to represent the width and height of image information.

Red, green blue has 3 channels that contain the intensity of the RGB color. It needs a total of 3 bytes for 3 colors for pixels representation. Therefore it can illustrate more than 16 million different colors.

In OpenCV the image load in this format which is the same as RGB in a different order (6).

This also has 3 channels though the representation is hue. It considers the saturation, The amount of color light/dark, and the value or intensity of the image like the brightness of color.(4)

D. Edge detection. For image analysis, edge detection comes with huge local changes. It is most important to identify the feature in the image. There are several edge detection algorithms available though due to their quality, instill in the research area. There is plenty of edge detection algorithm in the market and each of them has its pros and cons. Canny edge detector, Prewitt operator, Sobel operator, Laplacian operator are the most popular ones. There in the study, we are seeing the figure of canny edge detection. A photographic device captures the low-frequency picture. Due to this many edge lines are detected so, the edge detector can find as it is the algorithm that underlines the set of edges from the image.

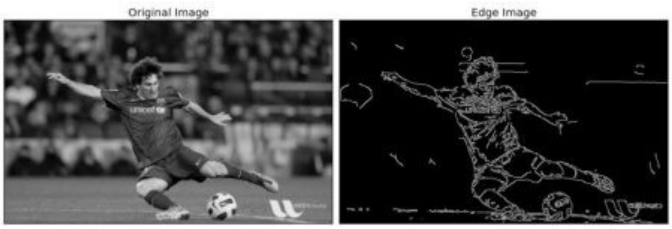

Fig. 1. canny operator example (7)

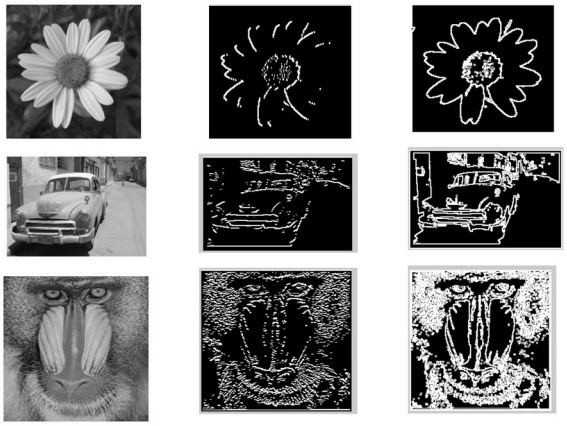

Fig. 2. sobel operator example (8)

E. Machine learning. The machine learning performance is compared to a simple baseline model. Defined by always predicting the mean IRI of the training data set. In this study, we considered the linear and regularized linear models, k-Nearest Neighbors, Random Forest, Support Vector Machine, and Multi-Layer Perceptron Neural Networks. For classification, consider the Naive Bayes model. For models implementation, we can use the sklearn library.

F. Deep learning. For various image analysis research projects deep learning is one of the hot topics. In deep learning, YOLO is the most widely used tool. It has a darknet framework based on an Artificial neural network (ANN). BBOXtool is also a very useful tool for classification and labeling.

Multilayer perceptron (MLP) is a class of feedforward ANN. The architecture consists of three different layers. The Innermost layer (input layer) received the input features x, an arbitrary number of hidden layers where the computation is done, and the Outermost layer (output layer) which outputs the prediction. Every layer is formed by one or multiple operations, e.g. neurons that compute a linear combination of the outputs from the previous layer. The non-linearity is incorporated into the model by passing the output through an activation function. In this study, we see the RELU activation function at the end of each hidden layer.

Methodologies

G. Data set. The data set is consists of 5 different type of road surface. Each surface have different IRI value. For more than 2000 pictures, we are assuming it can produce better results.

H. surface and cracks detection. We can divide the road surface in different category based on the surface smoothness. To find good road conditions we can consider major criteria. The number of cracks line based on IRI. We need to prepossess the image to find the region of interest, cut the necessary information. After that, we have to morphological

Fig. 3. dataset (9)

Fig. 4. dataset (9)

operations to remove extra pixels. Canny edge detection also should be applied to find a line around the cracks.

Algorithm Image enhancement – Image restoration – Image segmentation – Input to KNN – Roughness detection

The algorithm should works in real-time with webcam. We can a recorded mp4 video for the convenience of this project. Algorithm can describe in three parts. First, we have to convert the video into frames than resize it which is prepossessing part. Second, processes the image with erosion and median blur to reduce the noise. The median filter can be use for this. It brings the smoothness to the image. With this many unwanted counter can appear in the image which require extra computational resources. Erosion operation of morphological operation which has been applied to structuring the element and removing noise.

It reduce small details from the binary images. Lastly, a Canny edge detector can applied to the eroded image which produce the edge in perfect condition. By this it is possible to find all the edged elements, most of them are cracks and tiny objects.

Result

The performance evaluation for different classes is visualized via confusion matrices. For the models trained on the PCA

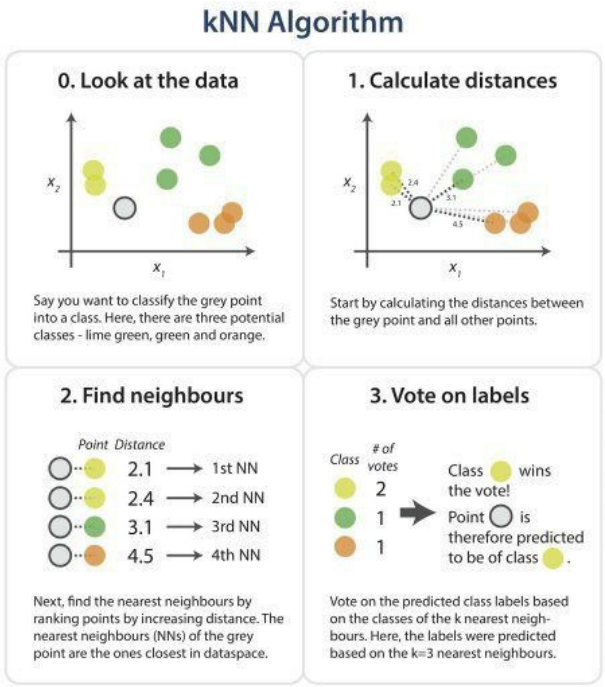

Fig. 5. KNN Algo (10)

transformed subset. The rows show the true class, while the columns show the predicted class. A good performance of model is indicated by the fact that most of all predictions fall onto the diagonal, which indicating the correct prediction and that the mislabeled classes are in majority of cases assigned to the neighboring class.

Conclusion

In this case, the study mainly focused on road roughness (cracks) detection with image processing methodology. This is better than the traditional methodology. The result of these techniques and the deep learning model can be scaleless to real-time road condition detection. This system alters a driver and the output of this can be used for controlling the unit of the vehicle. We can see that other models can be integrated with this system.

Future work

After implementation of this work into an application, this application can be used for different purposes. Many researchers are still working for the perfection because some of this type of work are not performing in real time perfectly. There are many false-positive also detect in clear weather condition (mostly sunny). But con appears in the night and dark weather. There are other many issue with the surface like signs direction on road. Considering these cons we still have a lot to work on.

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