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Evaluation of Classification Algorithms for Road Environment Detection

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Abstract**—**The road environment information is needed accurately for applications such as road maintenance and virtual 3D city modeling. Mobile laser scanning (MLS) produces dense point clouds from huge areas efficiently from which the road and its environment can be modeled in detail. Objects such as buildings, cars and trees are an important part of road environments. Different methods have been developed for detection of above such objects, but still there is a lack of accuracy due to the problems of illumination, environmental changes, and multiple objects with same features. In this work the comparison between different classifiers such as Multiclass SVM, kNN and Multiclass LDA for the road environment detection is analyzed. Finally the classification accuracy for kNN with LBP feature improved the classification accuracy as 93.3% than the other classifiers.

Keywords**—**Classifiers, feature extraction, mobile-based laser scanning, object location estimation.

I. INTRODUCTION

AN emerging interest in accurate 3-D information has revealed in recent years. The 3-D information can be used in the planning and maintenance of road and street environment. MLS technology combines different sensors to efficiently collect accurate 3-D point clouds from large areas [10].

The information extracted from the 3-D laser dataset collected using a MLS system requires many hours of manual inspection. That is, it is necessary to manually inspect the dataset to identify specific objects. So, to reduce the need for human interpretation, some automatic methods are required to efficiently process the objects in the road environment.

Different types of automatic methods have been developed for MLS point cloud classification. To detect the object, the point cloud is first segmented to extract the required objects. Then a set of features such as size, shape or some other features that describes the characteristics of the object is calculated for the segmented objects [9]. Then, the classification is performed to detect the objects. The main objective of this study is to compare the three classifiers Multiclass SVM, kNN and Multiclass LDA and to decide which one is suitable for the classification purpose.

A. Related Work

The research in object detection in road environment keeps on increasing by developing various methods and feature sets. Some of the significant works related to object detection in a road environment are listed below.

Valentino et al. [1] analyzed the use of methods in computer vision and developed a classification and segmentation system that is used for labeling objects which are present in the road and then concludes with suggestions on how functionality could be incorporated to increase performance. Halgas et al. [2] described some formulas which are used to process the distance and position in the 3D coordinate system. Then the processed data create a cloud of points where each scanned point is therefore classified into one of the groups of objects found in the road environment. Fernandez et al. [6] presented a comparative analysis of decision trees based classifiers and made many tests to get the best parameters configuration and obtain the importance of each feature in the final classification. Riveiro et al. [8] worked in the detection and classification of retro reflective vertical traffic signs according to their function from MLS resulting in 83.91% accuracy. In MLS point clouds, Lehtomaki et al. [10] applied LDHs and Spin images for machine-learning-based object classification of the road environment and produced 87.9% accuracy.

B. Motivation and Justification

The information collected from the 3-D laser dataset using MLS in the road environment requires many hours to manually inspect the objects. So to reduce the need for human inspection, many automatic methods have been developed for MLS point cloud classification. Some of these methods are still lack of accuracy. So to find some better accuracy in detection, three classifiers have been compared.

C. Outline of the Work

In this paper, three classifiers are compared to detect the objects in the road environment. It contains two phases, namely training and testing. The feature in the input image is extracted in both training and testing phase. In both phases preprocessing technique is used to remove the noise from the input image. After preprocessing, the input image is segmented. Next the features are extracted from the segmented images. In training phase, the extracted features are stored in the feature database. In testing phase, the extracted feature is used for the classification. In classification, the extracted features from the testing phase and the training phase are compared to group the objects. Then the object location is estimated. These phases are shown in Fig. 1.

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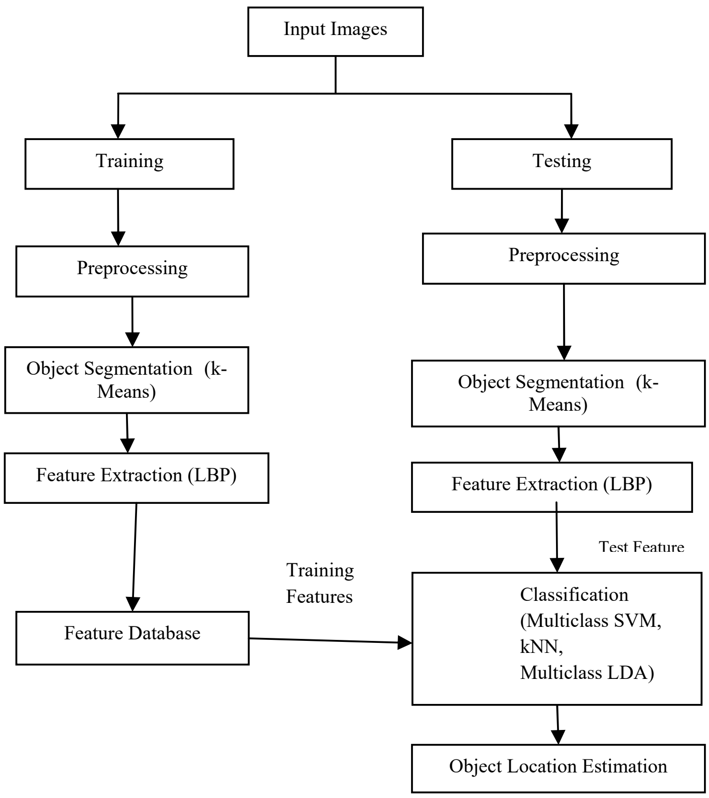

Fig. 1 Process flow for Object detection

D. Organisation of the Paper

Chapter II discusses about the methodology. The experimental results, performance analysis and its discussion are given in the Chapter III. In Chapter IV conclusions and the future scope are summarized.

II. Methodology

A. Preprocessing

The goal of preprocessing is to improve the image data that remove the unwanted pixels or enhance the image features which are used for further processing. The images taken from the road environment may contain noise. In this paper, the input images are preprocessed to remove unwanted noise. In this work, the noise is removed using median filter.

B. Object Segmentation

Segmentation is used to divide an image into multiple parts. This is typically used to retrieve relevant information in digital images. After preprocessing, filtered image is segmented to locate the objects present in the digital image. The segmentation is done using K-means algorithm, which has been previously applied to image annotation problem [7].

K-means is a clustering method that divides a collection of objects into K groups based on cluster center ‘C’. This will be done by computing the distance between each data point and cluster center ‘C’ present in the object. Among them, the data points having minimum distance from the cluster center ‘C’ will form a group. The remaining data points which are not having minimum distance will be processed again to form a new group. To form a new group, the new cluster centre 'C' can be calculated using (1),

$$V_j = \left(1/c_i\right) \sum_{j=1}^{c_i} x_i \tag{1}$$

where c_i represents the number of data points in i^{th} cluster. Repeat the procedure until each data point in the object are assigned to any one of the group.

C. Feature Extraction

Feature extraction represents the interesting parts of an image as a compact feature vector. After segmentation, the feature is extracted from the segmented image using LBP for classification. LBP means Local Binary Patterns which are used to extract the texture feature from the image. The procedure to extract the texture feature from the image using LBP is as follows: Divide the image window to cells such as 16 X 16 pixels in every cell. In a cell, compare the every single pixel to each of the eight neighbors in a clockwise or anti-clockwise direction. If the center pixel value is greater when compared to eight neighbor pixels, then write the value 1, otherwise write the value 0. At the end, it gives an 8-bit binary number. Compute the histogram in a cell and normalize the histogram. Finally concatenate the normalized histogram of all the cells in the image window. The result gives the feature vector for the image window [4]. This can be given by (2):

$$LBP_{X.Y}(m,n) = \sum_{X=0}^{X-1} s\big(f(m,n) - f(m_X,n_X)\big)2^X \qquad (2)$$

D. Classification

Classification is the action or process of classifying objects based on the similarity between the object and the description of the group. The main objective of this paper is to compare three different classifiers which are used to classify the point cloud segments. Using the features extracted from the segmented image, the classification has been performed with different classifiers. The three classifiers namely multiclass SVM (Support Vector Machine), kNN (k-Nearest Neighbors) and multiclass LDA (Linear Discriminant Analysis) are compared. An SVM is a binary classifier which constructs set of binary classifiers each trained to separate one class from another. The classes are then combined to get a multiclass classification [4]. In kNN, a positive integer such as 'k' will be specified with a new sample. In the feature set, we select 'k' number of entries which are closest to the new sample. Then from the selected 'k' number of entries, the classification is performed [5]. LDA is a classifier which is computing the mean of the scatter matrices by solving the Eigen value of the matrix.

E. Object Location Estimation

The location of the objects was estimated after the classification of the segmented image. The output of the process gives the labeled object locations. The objects are detected by where the buildings are labeled using white color, cars are labeled using grey color and the trees are labeled using black color [3].

III. Experimental Results Analysis and Discussion

A. Dataset

The Sun Databases dataset contains 60 images for training and 30 images for testing. Images on the database are captured from various places (highway, urban, rural) and during various times (morning, afternoon, etc.). The dataset contains more than 100 road environment images from different categories. Three main categories of road environment are buildings, cars and trees which are selected as the target classes in competition and in our experiments. The resolutions of the images vary from 126 x 126 pixels to 1286 × 1286 pixels. Finally, all the images are resized into the common pixel level as 256 x 256. Some of the road environment images are shown in Fig. 2.

Fig. 2 Sample Input Images

B. Experimental Results

The experiment is conducted based on three classifiers such as multiclass SVM, kNN, multiclass LDA and the performance of the experiments are analyzed using metrics. The input images were segmented based on the required objects. Then the feature is extracted from the segmented images and the classification is performed. As a result, the location of the required objects are labeled and estimated. Some of the results are shown in Fig. 3.

C. Analysis and Discussion

1. Performance Metrics

Performance Evaluation is used to compare different techniques in image processing. It is mostly used to measure the quality of the process. The performance metrics such as Sensitivity, Specificity and Accuracy are used in this paper to compare the three different classifiers. The Sensitivity is computed using (3)

$$Sensitivity = \frac{TP}{TP+FN} \qquad (3)$$

The Specificity is calculated using (4)

$$Specificity = \frac{TN}{TN+FP} \qquad (4)$$

Equation (5) is used to compute Accuracy

$$Accuracy = \frac{TP+TN}{TP+FN+FP+TN} \qquad (5)$$

The performance metrics are computed using TP (True Positive), FN (False Negative), TN (True Negative) and FP (False Positive). TP denotes the number of correctly identified objects, FN denotes the number of incorrectly rejected objects, TN denotes the number of correctly rejected objects and FP denotes the number of incorrectly accepted objects.

2. Performance Evaluation Based on Multiclass SVM

Table I shows the performance analysis of each object in the road environment detection using the metrics Sensitivity, Specificity and Accuracy for the classifier Multiclass SVM.

TABLE I
PERFORMANCE ANALYSIS ON MULTICLASS SVM

Objects	TP	FN	FP	TN	Sensitivity	Specificity	Accuracy
Building	7	3	4	16	0.7	0.8	0.77
Car	7	3	4	16	0.7	0.8	0.77
Tree	6	4	2	18	0.6	0.89	0.8

From Table I, it could be observed that the accuracy of the objects such as buildings, cars and trees in a road environment which are detected using the classifier Multiclass SVM is nearly 60 to 89 %.

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Fig. 3 Experimental Results of Object detection

3. Performance Evaluation Based on kNN

Table II shows the performance analysis of each object in the road environment detection using the metrics Sensitivity, Specificity and Accuracy for the classifier kNN. According to Table II, the classifier kNN detects the objects in a road environment such as buildings, cars and trees accurately and gives the better result. It is nearly 80 to 95%.

TABLE II
PERFORMANCE ANALYSIS ON KNN

Objects	TP	FN	FP	TN	Sensitivity	Specificity	Accuracy
Building	9	1	1	19	0.9	0.95	0.93
Car	9	1	1	19	0.9	0.95	0.93
Tree	8	2	2	18	0.8	0.9	0.87

4. Performance Evaluation Based on Multiclass LDA

Table III shows the performance analysis of each object in the road environment detection using the metrics Sensitivity, Specificity and Accuracy for the classifier Multiclass LDA. From Table III, it is understood that the classifier Multiclass LDA detects the objects such as buildings, cars and trees in a road environment accurately and the results are nearly 60 to 90%.

TABLE III
PERFORMANCE ANALYSIS ON MULTICLASS LDA

Objects	TP	FN	FP	TN	Sensitivity	Specificity	Accuracy
Building	6	4	2	18	0.6	0.9	0.8
Car	8	2	5	15	0.8	0.75	0.77
Tree	7	3	2	18	0.7	0.9	0.83

5. Comparison of Classifiers

Table IV shows the comparison of performance of three classifiers Multiclass SVM, kNN and Multiclass LDA for detecting the road environment. From Table IV, it could be observed that the Multiclass LDA performs better than Multiclass SVM but kNN performs better than both Multiclass SVM and Multiclass LDA. From this result, it could be concluded that the classifier kNN performs well using the feature LBP.

TABLE IV
COMPARISON OF CLASSIFIERS

Classifiers	Sensitivity (%)	Specificity (%)	Accuracy (%)
Multiclass SVM	66.7	83.3	78
kNN	86.7	93.3	91
Multiclass LDA	70	85	80

IV. CONCLUSION

In this work, the performances of the classifiers such as Multiclass SVM, kNN and Multiclass LDA are compared. The experiments have been conducted and the performance has been evaluated using different metrics. From the analysis, we could conclude that the kNN classifier with LBP performs better than other classifiers. The reason for this better performance is that the LBP can extract the texture information from any objects and the kNN works better for classifying the texture properties. As the road environment is a combination of multiple objects, the LBP highly supports for feature extraction. The k-means segmentation method boosts the classification as high as possible and gives better segmentation between the objects. Finally the combination of LBP with k-means segmentation and kNN classifiers outperforms other combination in the road environment detection.

In future the accuracy can be improved by developing the new color, shape or texture features. The new segmentation algorithm can be proposed. The small objects in the road environment will be considered.

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