Research on Recognition Method of Truck Colors Based on Convolutional Neural Network Model

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Abstract—**Truck color is one of the important information of vehicle ownership in intelligent transportation system. Aiming at the problem that truck color recognition is easy to be affected by complex scene and illumination changes, this paper studied the truck recognition method based on convolutional neural network, constructed the truck color image set, transformed truck vehicle image samples into RGB, HSV, and LAB color spaces. A truck color recognition method based on convolutional neural network model is proposed and experimental research is proposed. The experimental results show that the performance of the proposed convolutional neural network model based on LAB color space is better than that of proposed convolutional neural network model based on HSV color space, and achieved a verification accuracy at 96.36%.**

Keywords—Intelligen Transportation System (ITS), Vehicle Ownership, Convolutional Neural Network (CNN), Truck Color, LAB Color Space

I. INTRODUCTION

Truck recognition is one of the key important methods of truck attribute recognition, which is widely used in the fields of vehicle recognition in expressway scene, non-stop charging, truck violation inspection and so on. Truck color information is one of the key information of vehicle besides truck license plate information. By truck color recognition, the weakness of vehicle recognition based on single vehicle attribute could be made up, which could play an important role in combating false license plate. However, because of the influence of factors such as long vehicle driving time, complex road scene and illuminations changes, it is difficult and challenging to realize accurate recognition of truck color through truck image. Therefore, how to realize the accurate recognition of truck color through truck image has become an urgent problem to be solved in the field of intelligent transportation system. In 2017, Xue et al. [1] adopted a vehicle image fusion processing method including histogram equalization method, local contrast enhancement and homomorphic filtering method to process the vehicle image and improve the accuracy of vehicle color recognition. In 2017, Aarathi et al. [2] proposed a method to solve the problem that vehicle images taken from roads or hill areas could not be effectively recognized because of haze, which mainly adopts the dark channel prior technique and CNN to remove the haze and learn feature respectively. In 2018, Kim et al. [3] proposed a vehicle color classification method based on representative color region extraction and convolutional neural (CNN), which randomly selects points from the probability map of representative color region produced by Harris corner detection method to generate an input image for CNN model training. In 2018, Zhang et al. [4] proposed a vehicle color recognition method based on a lightweight CNN which contains three convolutional layers, a global pooling layer and a fully connection layer. Compared with traditional vehicle color recognition method, this method could reduce the dimension of feature vector and the memory occupation of the model, at the same time improve model accuracy slightly. In 2019, Sun et al. [5] integrated the trained vehicle brand recognition network and vehicle color recognition network based on the training mode of multi-task learning, and constructed a vehicle multi-attribute recognition model. In 2019, Zhang et al. [6] built a vehicle color recognition network model based on deep convolution neural network by adjusting structure and parameters of Deep-VGG-16 model. In 2020, Fu et al. [7] put forward a multi-scale comprehensive feature fusion convolutional neural network (MCFF-CNN) based on residual learning to solve the problem of automatic vehicle color conditions, which first extracts the dark color features of vehicles through MCFF-CNN network, and then through support vector machine (SVM) classifier to obtain the final color recognition results. In 2021, Tariq et al. [8] proposed a vehicle detection and vehicle color classification method based on Faster R-CNN to solve the problem that the commonly used recognition methods rely heavily on hand-made features. In 2021, Awang et al. [9] studied at the impact of different schemes of color images on the performance of vehicle type recognition system, and compared the performance of vehicle feature extraction models under YCrCb and RGB color schemes. In 2021, Hu et al. [10] built a vehicle color database contains 24 vehicle colors and proposed a Smooth Modulated Neural Network with Multi-layer Feature Representation (SMNN-MFR) to solve the problem of long tail distribution in the dataset.

At present, the research on truck color recognition is still considered as a part of the research of vehicle color recognition in a broad sense. However, due to the problems of low body cleanliness of truck, changeable road lighting and weather conditions caused by long-time driving, truck body color recognition is more difficult and challenging than other types of vehicle color recognition, Therefore, it is necessary to study a specific color recognition method of trucks according to the special characteristics of trucks.

The content of this article is arranged as following: The first is introduction, which mainly introduces the research background of this article. The second part is related work, which mainly introduce the methods and theories of truck color image data set construction and truck color recognition. The third part is experimental results and analysis. And the fourth part is the conclusion.

II. METHODOLOGY

A. *Color space theory*

1) RGB color space

RGB color space is a color space based on trichromatic principle, which could express most colors in nature by adjusting the brightness of red (R), green (G) and blue (B) and superimposing them. The three primary colors are independent of each other. None of primary colors could be superimposed by the other two colors. As shown in Fig. 1, by trichromatic principle, the required color C could be configured through RGB color, which means by adding and mixing three primary colors.

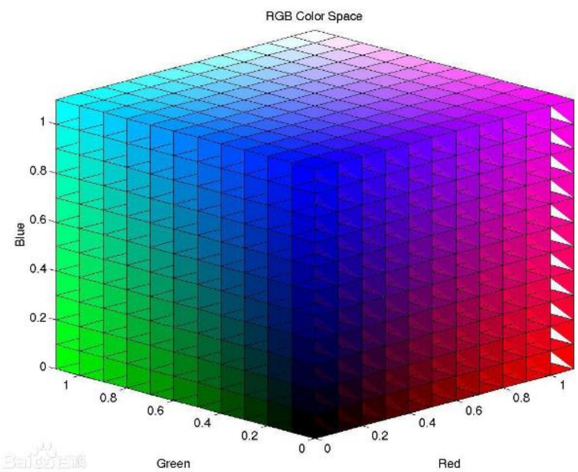


Fig. 1. RGB color space

2) HSV color space

HSV color space is a color representation method according to the intuitive characteristics of color, which map points in RGB color space into the cone model. In HSV model, H means hue, which represents color category, with the value range between 0° and 360°. S means saturation, which indicates the degree to which the color is close to the spectral color, with the value range between 0% to 100%, the more the proportion of spectral color, the higher the degree to which the color is close to the spectral color, and the more saturated the color is. V means value, which stands for the brightness of the color with the value range between 0% to 100%. The vertex of the cone model is the darkness point, indicating the pure black, and the center point of the cone ground is the brightness point, indicating pure white. The HSV color space is shown in Fig. 2.

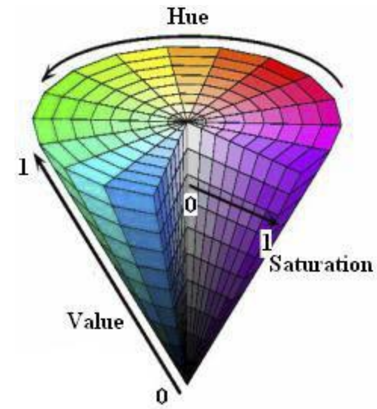


Fig. 2. HSV color space

3) LAB color space

LAB color space is a color space based on the international standard for color measurement formulated by the International Commission on illumination (CIE) in 1931. In LAB color space, L represents brightness, A and B are used to describe color. In an image, each pixel has a corresponding LAB value. L stores the brightness information of the image, the value range of it is [0,100], indicating from pure black to pure white. Component A represents the change from green to gray to red, and the value range is [-128,127]. Component B represents the change from blue to gray to yellow, and its range value is [-128,127]. The LAB model separates lightness from color. There is no color component in channel L, but only color component in channel A and channel B. Therefore, modifying the output of channel A and channel B could accurately represent the color, and channel L is used for brightness adjustment. The HSV color space is shown in Fig. 3.

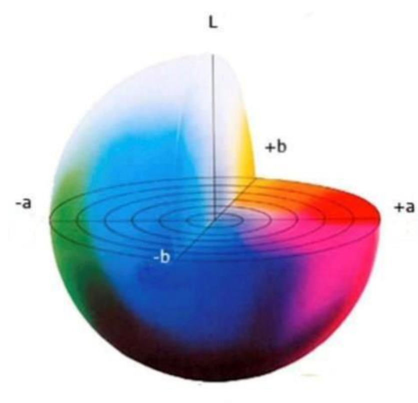


Fig. 3. LAB color space

B. *Truck color recognition method based on convolutional neural network*

Convolutional neural network is composed of convolutional layer, activation function, pooling layer full connection layer, dropout layer and so on. The main function of convolutional layer is to extract the local features of the input image and enhance the features of the input image. Each convolutional layer contains multiple feature planes, each feature plane represents a feature graph, and the number of convolutional cores determines the number of feature graphs. Activation function changes the linear hidden layer into a nonlinear function. The activation function gives the convolutional network the ability to classify nonlinear functions, meanwhile, it affects the convergence of the network model. Therefore, the selection of activation function has a great impact on the accuracy and speed of convolutional neural network. Because there would be a large number of redundant convolution values after the convolution operation. The feature of pooling layer is to reduce the redundant values, minimize the number of model parameters and further expand the receptive field while retaining the image information to the greatest extent. Through the convolutional layer, activation function layer and pooling layer, the convolutional neural network could effectively extract the features of the input information, that is, the data input data is mapped to the high-dimensional hidden feature space. The function of full connection layer is to map the distributed feature information of the high-dimensional hidden layer feature space to the sample space and act as a classifier. Dropout means that in the process of neural network training, some hidden layer nodes are temporarily discarded according to a certain probability and their weights are stopped. The discarded nodes could be temporarily identified as not part of the network structure, and these nodes would not be updated when updating the weights.

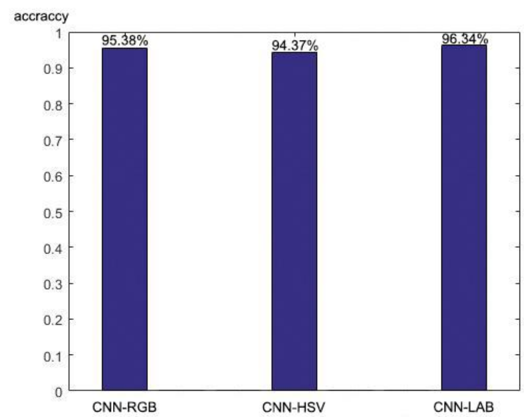
In this article, the structure of truck color recognition network based on convolutional neural network is composed of 1 output layer, 3 convolutional layers, 3 maxpooling layers, 2 full connection layers and 1 dropout layer. The input image of the whole convolutional neural network is three-channel image with the size of 64×128. The first convolutional layer adopts 32 convolutional kernels with a size of 3×3, chooses ReLU as the activation function, and connects with a pooling layer with a size of 2×2. The second convolutional layer also adopts 32 convolutional kernels with a size of 3×3, chooses ReLU as the activation function, and connects with a pooling layer with a size of 2×2. The third convolutional layer adopts 64 convolutional kernels with a size of 3×3, chooses ReLU as the activation function, and connects with a pooling layer with a size of 2×2. The extracted high-dimensional feature firstly connects with a full connection layer with 64 neural nodes, passes through the ReLU activation function, uses dropout with a dropout rate of 0.5, and finally connects with a full connection layer with 6 neural nodes, and then us Softmax to calculate the probability of truck color classification.

III. Experiments

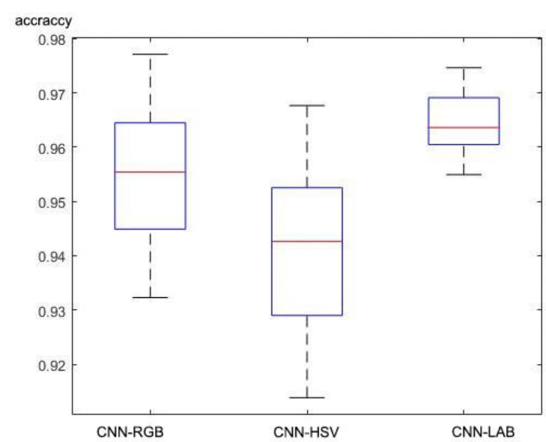
The experiment in this article is based on the SEU Truck Color Image Dataset (STCID), 60% of 1492 images in this dataset are used as training image, 20% of them are used as verification image and the remaining 20% images are used as test image. There are 6 types of truck color in this dataset, which are red, blue, white, yellow, green and black. The image set is transformed into HSV color space and LAB color space respectively, to obtain the image samples in three color spaces, and the three kinds of samples are input into the constructed convolutional neural network for training. In order to reduce the influence of redundant information brought by the air inlet hood with different color of the front face of the truck, the local area image of the front face of the truck is directly segmented to extract the left and right color block areas that do not include the air inlet hood, and then the color block areas are input into convolutional neural network to train. In the process of model training, the cross entropy loss function is selected as the loss function, and RMSprop and Adam are used as the optimizer for comparative experiments. The experimental results of CNN-RGB, CNN-HSV and CNN-LAB using different optimizers are shown in Table I. According to Table I, the difference of optimizers has little impact on the model accuracy, which belongs to the normal error range. Therefore, it could be concluded that the selection of optimizer has little impact on the accuracy of convolutional neural network model.

TABLE I. Comparison of Model Accuracy of Different Optimizers

	optimizer=RMSprop		optimizer=Adam	
	Train-Accuracy	Valid-Accuracy	Train-Accuracy	Valid-Accuracy
CNN-RGB	0.9648	0.9595	0.9708	0.9538
CNN-HSV	0.9536	0.9438	0.9615	0.9437
CNN-LAB	0.9769	0.9651	0.9808	0.9634



(a) Bar Plot of Recognization



(b) Box Plot of Recognization

Fig. 4. Comparison of accuracy of three models

The experimental results of truck color recognition method based on convolution neural network, which based on CNN-RGB, CNN-HSV and CNN-LAB color spaces respectively, with RMSprop optimizer are shown in Fig. 4. According to the histogram in Fig 4 (a), the accuracy of the convolutional neural network based on LAB color space is 96.34%, which is slightly higher than those of the convolutional neural network models based on two other color spaces. The convolutional neural model based on RGB color space has an accuracy of 95.38%, which performs second best. The convolutional neural model based on HSV color space performs the worst with an accuracy of 94.37%. Fig. 4 (b) is the box diagram of three models, according to Fig. 4 (b), the average accuracy of the convolutional neural network model based on LAB color space is higher than that based on RGB color space, and the accuracy distribution span is smaller than that based on RGB color space, which means that the convolutional neural network model based on LAB color space not only has better performance, but also has better robustness and stability. The confusion matrix of truck color recognition experiment results based on convolutional neural network model is shown in Table II. According to the confusion matrix, the correct classification rate of red and yellow is higher, followed by blue. The probably reason causing the higher correct classification rates of these two colors is may be these two kinds of colors have richer characteristics compared with other colors.

TABLE II. CONFUSION MATRIX OF TRUCK COLOR RECOGNITION EXPERIMENT RESULTS

Class	Red	Blue	White	Yellow	Green	Black
Red	99.06%	0.31%	0	0.63%	0	0
Blue	0	96.88%	1.04%	0	2.08%	0
White	2.07%	0	93.10%	4.83%	0	0
Yellow	0	0	0	100%	0	0
Green	0	12.5%	0	0	87.5%	0
Black	0	14.29%	0	0	0	85.71%

IV. CONCLUSIONS

In this paper, RGB color space, HSV color space and LAB color space are compared and analyzed, and the image samples of trucks are transformed into RGB, HSV and LAB color space respectively; A convolutional neural network model for truck color recognition is constructed, and the effects from RMSprop optimizer, Adam optimizer on the accuracy of the model are compared and analyzed. The experimental results based on the SEU Truck Color Image Dataset show that the selection of optimizer has little impact on the accuracy of the model. There are differences in the accuracy of truck color recognition models in different color spaces. The truck color recognition model based on convolutional neural network in LAB color space has better accuracy, and its accuracy reaches 96.34%. Meanwhile, colors of trucks also have an impact on the color classification accuracy. The best classification effect could be achieved for red and yellow Trucks.

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