TRB Annual Meeting

Image Recognition Based Traffic Sign Facilities Damage Detection

--Manuscript Draft--

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Manuscript Classifications:	Infrastructure; Highway Maintenance; Roadside Maintenance Operations AKR20; Roadside Maintenance; Infrastructure Management and System Preservation; Tactical Asset Management AKT80; Maintenance Data Collection; Infrastructure condition assessment
Manuscript Number:	TRBAM-21-01030
Article Type:	Presentation and Publication
Order of Authors:	Runhua Guo
	zhijian cao

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CAO zhijian
Graduate Student
Department of civil engineering
Tsinghua University, Beijing, China,100084
Email: caozj17@mails.tsinghua.edu.cn

GUO Runhua (Corresponding Author)
Associate Professor
Department of civil engineering
Tsinghua University, Beijing, China,100084
Email: guorh@tsinghua.edu.cn

Word Count: 3207 words + 1 table (250 words per table) = 3,457 words

Submitted [2020-7-31]

ABSTRACT

Traffic sign facilities are an important part of the road system. The inventory of these facilities lays a foundation for a digital and modern management platform. In the subsequent maintenance, it is also necessary to collect the damage information on the sign facilities. The efficient approach to the facility damage information is through automatic detection and recognition.

At present, there are many algorithms for traffic sign recognition, but there is not much research on damage recognition. This paper discusses the basic principles and methods of traffic sign recognition. Furthermore, this paper introduces a difference comparison method and a threshold segmentation method of damage recognition. Both two methods can recognize the damage information in a certain situation, but they all have their own limitations.

keywords: Traffic Sign, Image Processing, Damage Recognition.

INTRODUCTION

Traffic sign facilities are an important part of road assets. When building the road asset management platform, the management of traffic sign facilities is very important. When building the asset database, we need to recognize the traffic signs and store the recognition results in the database. In this process, an efficient and accurate algorithm needs to be designed, which can accurately recognition roadside traffic sign facilities and their means of these signs. In order to get information about all traffic sign facilities in road system, the recognition equipment needs to process every frame of scanned image. In this process, a lot of calculation is needed, and a lot of data will be generated. With the built database, the road management department can use detection equipment to scan images in places with traffic sign facilities, identify the damage of traffic sign facilities. This can effectively reduce the amount of calculation of image processing, avoid the large amount of calculation brought by processing of every detected image frame, and improve the detection efficiency.

There are many methods with high efficiency and accuracy for traffic sign recognition, but for traffic sign facility damage recognition, there are few researches at present. In other fields, there are some researches on damage recognition, which are all realized under ideal conditions, such as using white background when taking photos. However, for the traffic sign facility, the image information scanned by the detection equipment is usually complex. Only the target subject and background segmentation in the image needs a lot of work. **Figure 1** shows a simple process of traffic sign recognition and damage recognition. The author will explain the basic process and difficulties of damage identification of traffic signs from the basic principles of traffic sign recognition and damage detection, which paves the way for the subsequent work.

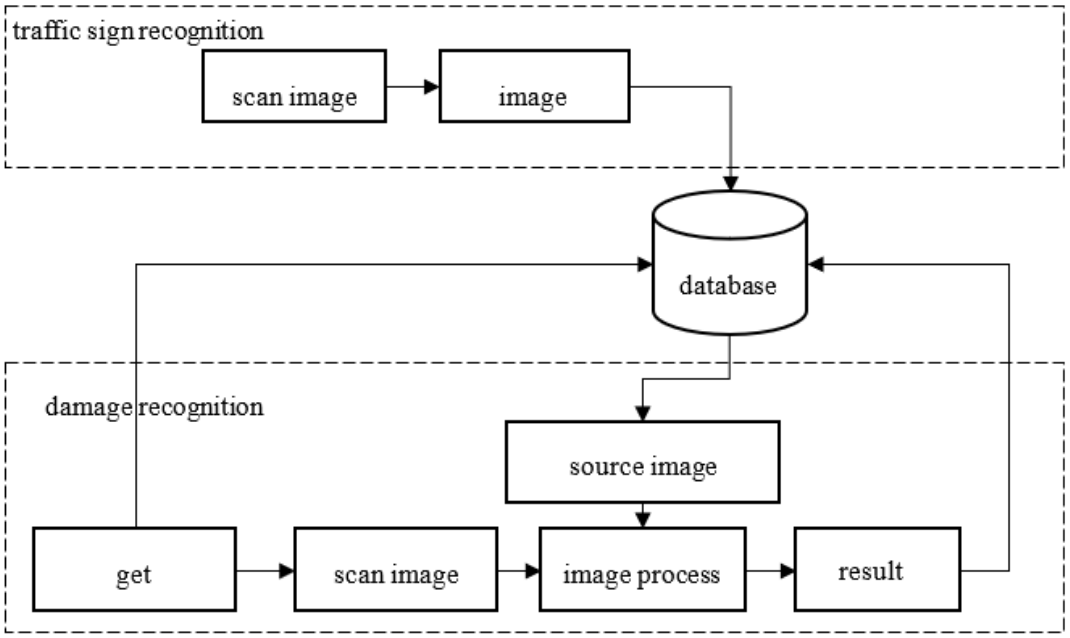

Figure 1 Process of traffic sign recognition and damage recognition

TRAFFIC SIGN RECOGNITION[1]

Traffic sign recognition can be divided into two main steps. The first step is position detection, the second is traffic sign semantic recognition. The main purpose of position detection is to detect the location of traffic signs from the image to reduce calculations for the step of semantic recognition. If we use a trained model to recognize the whole image directly, it will lead to a lot of useless calculations and reduce the efficiency of recognition.

Method of position detection

The detection of traffic signs' position is a key step in the process of traffic sign recognition. Accurately detecting the location of traffic signs on an image can greatly reduce the amount of calculation in the following recognition process. Typical detection methods include color based method, shape based method, multi-feature based method, and depth learning based method.

Color based detection method

Although there are many differences in traffic signs of different countries, most traffic signs are mainly red, yellow, blue and black in color. Therefore, using color to segment images can get better segmentation efficiency. Generally, RGB (red, green and blue) format (RGB color space, **Figure 2**) is used to represent the color of the image collected by the camera. Using RBG color format to segment the image can reduce some calculations, but RGB format is more sensitive to light. In a specific environment, it will be mixed with background noise. Therefore, RGB color space should be converted to HSV (hue, saturation, value) color space (**Figure 3**) before color segmentation in general. And using HSV color space can reduce the influence of light when splitting images by different colors. The value range of different colors in HSV color space is shown in **table 1**.

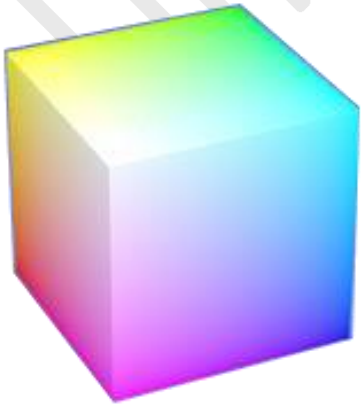

Figure 2 RBG color Space

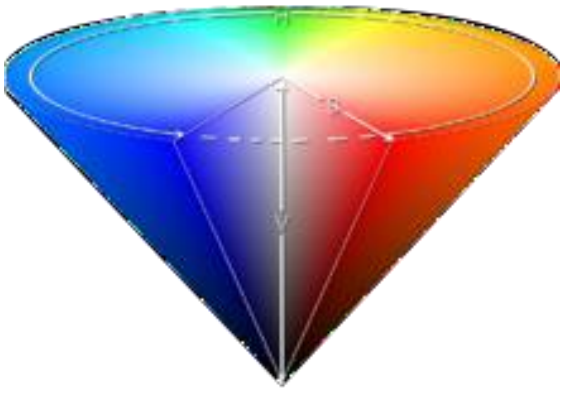

Figure 3 HSV color Space

Table 1 Value range of different colors in HSV color space

Color		Red		Yellow	Green	Blue
H	min	0	156	26	35	78
	max	10	180	34	90	124
S	min	43		43	43	43
	max	255		255	255	255
V	min	46		46	46	46
	max	255		255	255	255

Shape based detection method

Generally, the shape of traffic sign is different according to its meaning. As shown in **figures 4-6**, rectangle, circle and triangle are the most common shapes in traffic sign facilities. Therefore, using shape features[2] to detect traffic sign's position can accurately locate the right location, and the method is not easily affected by the background color.

Figure 4

Figure 5

Figure 6

Other methods

Using color or shape features to distinguish position has a high calculation speed, but because the traffic sign facilities in the actual road system are often affected by many aspects, such as the background is too complex, the resolution of image taken by the camera is inconsistent, the sign board is deformed or blocked, etc. It is easy to cause the accuracy of the segmentation method using single feature is very low. Therefore, there are actually multiple feature fusion detection methods that use multiple features to detect at the same time, this method can improve the accuracy of traffic sign's position detection.

Tang Kai[3] put forward a multi feature collaborative method of color feature, shape feature and scale feature to solve the problems of detection omission caused by color distortion, shape distortion and scale change in traffic sign's position detection, which uses multi threshold segmentation method and closed contour curvature histogram chain code, and uses SVM (support vector machine) classification to obtain detection results. The algorithm can effectively improve the detection accuracy of traffic signs in low time complexity.

In addition, there is a position detection method based on deep learning. The deep learning method extracts features through training and learning, which is quite different from the previous methods. In practice, there are many algorithms and networks, such as RCNN, SPP-

Net, Fast RCNN, Yolo network, which can achieve higher accuracy than traditional algorithms. Traffic sign position detection based on deep learning can learn features by training a large number of samples, which has strong anti-interference ability and is not easily affected by light, and other factors. It has a good application prospect in practice.

Traffic sign semantic recognition method

When traffic signs positions are detected, the semantics of traffic signs need to be recognized. The main methods of traffic sign semantics recognition method include template matching, machine learning and deep learning.

Method based on template matching

The recognition algorithm based on template matching is simple. The pre-set target image template is used as the search target, then search template image in images which need to be recognition (target image). If there are images found by using a specific algorithm match the template, which means the matching is successful. As the semantics of the template image is known, as long as the template is matched in the target image, the semantics of the traffic signs represented by the target image can be obtained according to the semantics of the template image. However, for traffic signs, due to the wide variety of traffic signs, it is necessary to match all the traffic sign image templates on the target image one by one when using template matching, which makes the amount of calculation very large, and it is difficult to meet the requirements of real-time recognition.

Method based on machine learning and deep learning

The recognition results of template matching method are easily affected by the deformation, damage, occlusion of the target image, so this method is difficult to meet the requirements in both computing time and robustness.

The algorithm based on machine learning uses a supervised learning method that extracts features manually and then uses machine learning. This algorithm is more efficient than template matching algorithm. The commonly used manual extraction features methods include scale invariant feature transform (SIFT[4]), orb feature, Gabor wavelet feature[5] and direction gradient histogram feature. The commonly used machine learning classification algorithms include support vector machine (SVM), decision tree, BP neural network, etc. Using machine learning for recognition can achieve better recognition and classification results, but it needs to extract the target features manually, which is cumbersome in operation, and the selection of features will significantly affect the learning effect.

Deep learning recognition method does not need to extract features manually. Just need input the image of the model, and then use deep convolution neural network (CNN) to complete feature extraction and classification through supervised learning with high recognition accuracy. This algorithm is helpful to solve the difficulties of traffic sign recognition under the condition of light change and partial occlusion.

There are some open deep learning platforms. Users can train their models through simple tags without considering the specific implementation of the underlying layer, such as the ModelArts provided by Huawei cloud.

Figures 7-10 shows the results of part of traffic sign recognition using model trained by ModelArts. Using the recognition method based on deep learning can achieve high accuracy. This method needs a large number of training samples when training the model. With the increase of the number of samples and the increase of scenes in the samples, the recognition result will be better.

Figure 7

Figure 8

Figure 9

Figure 10

DAMAGE RECOGNITION OF TRAFFIC SIGN FACILITIES

There are various types of damage on traffic sign facilities, which can be divided into two categories according to the location of the damage. The first type is the damage of the main body of the sign; the second type is the damage of the supporting facilities. As shown in **figure 11**, the support facility and main body all be damaged, for **figure 12**, just the main body has some damage.

The structure of the supporting facilities is relatively simple, and the main damage is tilt, deformation, etc., while the geometric shape of the main body of the sign is relatively simple.

However, due to the main body need to convey certain semantic information, the types to be considered for the damage are more complex, and the damage mainly includes deformation, missing, surface stains, paint falling off, resolution reduction, etc.

Figure 11

Figure 12

Damage identification of traffic sign supporting facilities

The damage of traffic sign supporting facilities is mainly caused by geometric form. Because it does not convey semantic information, so it is easy to realize in damage identification. To recognize the inclination of supporting facilities, we need to find the straight line of supporting facilities such as the outline of a pole from the input image, and then judge the slope of the straight line. The general method of line detection is Hough transform line detection method.

In the *x-y* coordinate system, a line can be expressed as

$$y = k * x + b \tag{1}$$

Where *k* and *b* are parameters, respectively representing the slope and intercept of the line. The equations of all lines passing through a point *P* (x_0, y_0) are satisfied

$$y_0 = k * x_o + b \tag{2}$$

That is to say, point *P* determines a group of straight lines and rewrites formula (2) as

$$b = -k * x_o + y_0 \tag{3}$$

Then the equation (3) represents a straight line in the parameter space *k-b*.

Therefore, a point *P* (x_0, y_0) in *x-y* space represents a straight line in parameter space. For the two points P_1 and P_2 that determine a straight line ($y=k_0*x+b_0$) in the *x-y* space, they correspond to the two straight lines intersect at point $P_3(k_0, b_0)$ in the parameter space. Therefore, a line in *x-y* space corresponds to a unique point in parameter space. The coordinate of this point (k_0, b_0) is the corresponding parameter of the line in *x-y* space.

Therefore, in line detection, the points in the original image can be transformed into the parameter space first, and then the points whose intersection times are greater than threshold

can be counted in the parameter space. The coordinates of these points are the parameters of the lines in the original image.

It should be noted that the rectangular coordinate system in the parameter space is not suitable for the line with an infinite slope, so the polar coordinate method is generally selected as the parameter space to detect the line using Hough transform in practice. Moreover, The calculation result of Hough transform is very sensitive to the threshold value, which needs to be adjusted according to different scenes.

Figure 13 is the result of image edge detection. **Figure 14** is the result of line detection by Hough transform using the result of edge detection. It can be seen that the inclined support rod can be described by the detected line very well.

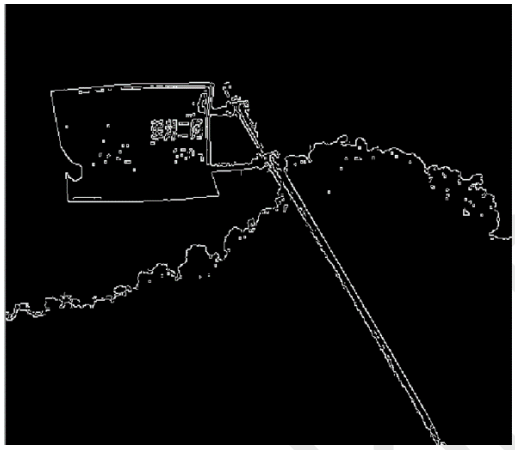

Figure 13

Figure 14

Damage identification of main body of traffic sign

The damage of the main body of the traffic sign is complex. After the image converted to gray texture image, the surface stains, paint peeling off, etc. will be changed into the surface color information without changing the contour of the sign. The missing and deformation seriously affect the shape of the outer contour of the sign, which makes it difficult to identify. The decrease of saturation shows the uniform change of image color value.

For the missing and deformed of the sign boards, the same contour[6] as the image template can be used for fitting. For damage identification, the fitted contour can be used to replace the contour of the signboard in the actual image. For the missing part and surface stains caused by deformation, the same treatment can be done, and the damaged area includes both two damage. In the process of damage identification, the method based on template matching and difference comparison and the method based on gray image threshold segmentation can be used.

Method of difference comparison based on template matching

Because the color of the damaged part of the signboard is different from that of the normal situation, the damage information can be obtained by comparing the color information of the

target image and the template image. For example, **figure 15** is a damaged signboard, and **figure 16** is a template image without damage. The gray value of the two figures can be calculated by difference, and the result of **figure 17** can be obtained. The area where the gray value in figure 17 is greater than the given threshold can be counted, thus damage information of whole image can be obtained.

Figure 15

Figure 16

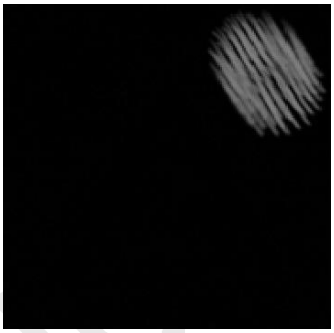

Figure 17

There are some limitations in this method. First of all, we need to match the position of the target image and the template image strictly, and the size of the two images should be the same. For the target image, its angle and position are often quite different from the template image. Before making color difference comparison, it is often necessary to process the target image through careful image segmentation, perspective transformation and other processes.

Corner is one of the most important features in local feature of an image, and it is often used in image matching. The methods of corner extraction can be divided into two categories: one is the corner extraction method based on image gray value, the other is the corner extraction method based on edge. The extraction method based on a gray image is simple, easy to operate and has high accuracy. So far there are many mature algorithms such as Moravec operator, Harris operator, SUSAN operator, etc.

Method of gray image threshold segmentation[7]

The damage recognition method based on color comparison has strict requirements for the detection image, which is often difficult to achieve in practical application. For the target image, the gray information of the damaged area is different from other areas. According to different gray information, the points in the image can be classified to realize the recognition of the damaged area. In the process of segmentation, it is necessary to set the threshold value of segmentation. Setting the threshold manually can achieve segmentation in a specific scene, but its universality is poor, and it is impossible to use this method of setting the threshold manually to recognition in practice. In practice, it is often using some algorithm to calculate appropriate thresholds for segmentation based on the gray value of the image. The commonly used threshold segmentation methods are iterative threshold segmentation, minimum error threshold selection, Otsu threshold segmentation and gray histogram threshold segmentation.

Figure 18

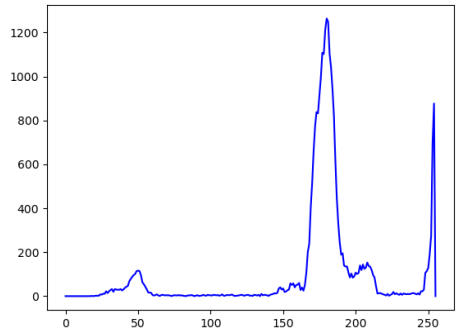

Figure 19

Figure 20

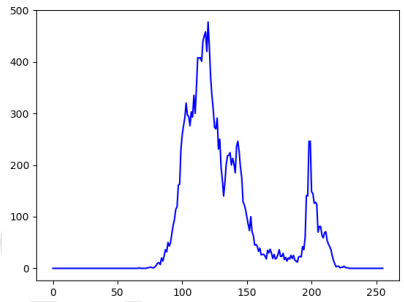

Figure 21

Figures 18-21 shows two kinds of signboards and their corresponding gray value histograms. Generally speaking, the points with higher wave peaks in the gray value histograms correspond to the main color in the image, and the range near the one peak corresponds to the damaged part. The threshold value can be selected as two troughs before and after the peak value. The damage information of the target image can be obtained by counting the points where the gray value is in damage range.

The threshold segmentation method based on gray value histograms does not have high requirements for the size of the images, but it is easy to be influenced by the background or image border color. Further improvement is needed in practice.

CONCLUSIONS

Traffic sign facility is a very important part of the road system, which is related to the safety of all road users and the operation efficiency of the whole road system. For the current road operation and maintenance, the automatic identification and warehousing of traffic sign facilities, damage identification and detection have a great influence on improving the management level, maintenance accuracy and real-time of the road management department.

Even to this day, great progress has been made in traffic sign recognition. There are many methods to achieve good results, no matter in accuracy or speed. There have been many attempts to identify the damage. Method of difference comparison based on template matching and method of gray image threshold segmentation in this paper can recognize the

damage information in a certain situation, but they all have their own limitations. There is no universal method, which needs further research and exploration in the future.

ACKNOWLEDGMENTS

First and foremost, I would like to show my deepest gratitude to professor Guo, who has provided me with valuable guidance in every stage of the writing of this paper. Without his guidance, I could not have completed my paper. His attitude towards scholarship enlightens me not only in this paper but also in my future study.

Last but not least, I' d like to thank all my friends, my parents, for their encouragement and support.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: CAO zhijian, GUO runhua; data collection: CAO zhijian; analysis and interpretation of results: CAO zhijian; draft manuscript preparation: CAO zhijian, GUO runhua. All authors reviewed the results and approved the final version of the manuscript.

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