Identification and Test Analysis of Scattered Objects in Traffic Accident Scene

Yanshu Ni\textsuperscript{1,a}, Qian Chang\textsuperscript{2,b}

\textsuperscript{1}Suihua college School of Electrical Engineering Suihua, China
\textsuperscript{2}Weifang Business Vocational College Weifang, China
\textsuperscript{a}601350111@qq.com, \textsuperscript{b}Changqian89@163.com

Abstract—The scattered objects contain a lot of important information on the scene of traffic accidents. The identification and extraction of relevant characteristic values of the scattered objects on the scene of traffic accidents can provide important basis for solving the collision speed of the vehicles in the accident and provide some evidence for the handling of traffic accidents. In this paper, scattered objects on the scene of traffic accidents are taken as the research object. According to the theoretical model of camera imaging and the characteristics of scattered objects in the accident site, a camera calibration system was proposed by combining with MATALB software. In order to reduce the error caused by background environment in the calibration process, the red calibration object with known structure size was designed to obtain the aerial photography image containing the calibration object. MATLAB was used to extract the calibration object in the image and establish the relationship model between the actual value of the calibration object and the image value. The image processing accuracy was improved by gray transformation, Wiener filter denoising, Laplace sharpening and Canny algorithm edge detection. Taking circular and irregular scattered objects as examples, the simulation test is designed. The proposed calibration method and image processing method are applied to identify the features of scattered objects. The identification results are calculated and compared with the actual measurement results to verify the accuracy of the proposed method and provide a reference for on-site accident treatment.

1. INTRODUCTION

With the rapid development of science and technology, more and more traffic accidents begin to use image processing technology to obtain accident site information. By using the computer program to convert the image information into digital signal, the target information can be obtained by processing the digital signal. In order to obtain the accurate scattering features of road traffic accidents, this paper studies and designs the camera identification and calibration system. By setting the characteristic value of the scattered objects, image processing is carried out on the photos of the accident scene through image processing technology, and feature recognition and parameter extraction are carried out on the acquired scattered objects image, which can make up for the scattered objects' unrecorded or incomplete information at the accident scene and provide some evidence for the traffic accident processing\textsuperscript{[1]}. 
2. DESIGN OF IMAGE PROCESSING CALIBRATION SYSTEM FOR SCATTERED OBJECTS

2.1. Image Processing Calibration System for Scattered Objects

• Calibration objects

The scattering object throwing distance model can solve the collision velocity of the vehicle when a traffic accident occurs. The relevant parameters in the model can be obtained by identifying the scattering object features in the image. According to the characteristics of the parameters in the throwing distance model and combined with MATLAB software, a simple and effective method is proposed in this paper. A red calibration block should be placed at the scene of the accident. The position of the calibration block should be as close as possible to the scattering objects to be identified. MATLAB software in the process of image processing image background environment requirements are very high, red is the most easy to distinguish and recognize the color, choose red calibration block can reduce the error caused in the process of image recognition.

Obtain the aerial photography images of scattered objects containing calibration objects in the accident scene, and obtain as many features of scattered objects as possible in an image. At the same time, to ensure the accuracy of feature recognition, the camera center should be kept at the lowest height. By using the method of overhead photography, the distortion error of the camera is zero, and the actual value of the scatter image and the pixel value become a simple proportional relation [2]. The selected red calibration block is shown in Fig.1. The actual size of the red calibration object is: length*width*height = 23*20*7.5.

2.2. Calibration object identification step

After reading the overhead photography image with MATLAB, the calibration objects are identified and extracted to obtain the pixel value. The specific steps are as follows:

• Clear the working interval, read and display the aerial photography image, extract the three components of the image, namely red (R), green (G) and blue (B), and calculate the red component. Call method is \( \text{bgrred} \). An efficient OTSU algorithm is used for binarization operation of image \( \text{red} \).

• The filling image supplemented the middle cavity, and the threshold \( a = 500 \) was selected to remove the noise less than \( a \), and the corrosion expansion method was used to remove other noises.

• All the elements of image \( \text{red} \) in the 2d binary image identified by the mark, the area distribution of the marked area is counted, the total number of the marked area is displayed, the minimum enclosing rectangle of the area is calculated by \( \text{BoundingBox} \) function, and the minimum enclosing rectangle of the red calibrated object is displayed.

• The length and width information of the minimum enclosing rectangle obtained is taken as the length and width of the calibration object. Since the actual length and width information of the red calibration object is known, the proportional relationship between the actual value of the object and the pixel value in the image can be established to determine the ratio \( r \).

• After identifying the calibration objects from the image and establishing the relationship between the actual value and the pixel value of the image, the relevant features of the scattered objects can be obtained according to the proportion relationship.
2.3. Identification of scattered objects in images

On the basis of camera imaging principle, the characteristics of the image analysis to identify the ratio between the need to build the image value and actual value, this paper proposed a camera calibration method is first to identify the calibration, calibration in the actual size of known, application of MATLAB software can recognize the image pixel values, according to the identification of the pixel can determine the image, and the relationship between the ratio between the pixel and the actual value for back analysis provides the reference for the identification of characteristic value[3]. Fig. 2 (a) shows the initial scattering object image, and Fig. 2 (b) shows the identification process of the calibration object.

![Image of initial and identified calibration object](image)

Figure 2. Calibration object recognition image

3. PREPROCESSING OF IMAGES OF DEBRIS AT THE ACCIDENT SITE

In this paper, MATLAB programming is used to realize the feature recognition and extraction of scattered objects images in traffic accident scene. It mainly includes gray transformation, histogram equalization, image smoothing, image sharpening and so on.

3.1. Image gray scale transformation and histogram equalization

In MATLAB, the function imadjust the gray scale of the image to enhance the contrast of linear transformation of gray image. Usage: s=imadjust(r, [low_in high_in], [low_out high_out], gamma). $r$ is the value in the original image, and $s$ is the value of mapping the value of image $r$ from low_in to high_out to low_out to high_out, so as to make the black part of the gray image more black and the white part more white and increase the contrast of the image. Gamma is the correction amount of image brightness adjustment, and the value of gamma is 2 in this paper.

In MATLAB, histeq function is applied to histogram equalization, and the specific call method is: $J = \text{histeq}(I)$. $I$ is the original input image and $J$ is the histogram after equalization.

3.2. Wiener filtering denoising

The purpose of image smoothing is to eliminate or suppress the noise of the polluted image and improve the image quality. In MATLAB, Wiener filtering is implemented using the deconvwnr function, specifically expressed as: $fr=\text{deconvwnr}(g, \text{PSF})$.

Among them, $g$ represents the degraded image, $f_r$ represents the restored image, and PSF is the point diffusion function. When the noise signal power ratio $S_n(u,v)/S_f(u,v)$ is 0, the Wiener filter is the inverse filter, and the grammatical form becomes: $fr=\text{deconvwnr}(g, \text{PSF}, \text{NSPR})$.

When the noise power ratio is a known constant or array, NSPR becomes an interactive scalar NACORR and FACORR input, and the output form becomes: $fr=\text{deconvwnr}(g, \text{PSF}, \text{NACORR}, \text{FACORR})$. NACORR and FACORR are autocorrelation functions of signal and original image respectively.

![Image of initial and Wiener filtered image](image)

Figure 3. Wiener filter image
The grayscale image of scattered objects is shown in Fig. 3(a), and the image after wiener filtering is shown in Fig. 3(b). As can be seen from Fig. 3(b), after wiener filtering, the target object is significantly compared with the background image.

3.3. Laplace image sharpening

The blurred image is caused by integration or averaging operation. In order to make the image clear, the image can be differentiated. Laplace sharpening is a common method of differentiation\(^4\). Laplace operator \(\nabla^2 f\) can be expressed as:

\[
\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}
\]

(1)

For the discrete digital image \(f(i, j)\), the first and second partial derivatives can be obtained, Laplace operator \(\nabla^2 f\) can be expressed as:

\[
\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = f(i+1, j)+f(i-1, j)+f(i, j+1)+f(i, j-1) - 4f(i, j)
\]

(2)

For image blur caused by diffusion, formula (3) can be used to sharpen the fuzzy image:

\[
g(i, j) = f(i, j) - \lambda \nabla^2 f(i, j)
\]

(3)

Where, \(\lambda\) is used to adjust the degree of Laplace sharpening. Laplacian operator is a second order difference algorithm which makes edge enhancement location more accurate. Fig. 4 shows the original grayscale image, the image denoised by Wiener filter and the image sharpened by Laplace. It can be seen from the image that Laplace sharpening effect is better.

![Figure 4. Laplace-sharpened image](image)

4. EDGE DETECTION FOR IMAGE FEATURE RECOGNITION OF SCATTERED OBJECTS

When obtaining the target object from the image, the edge feature is the most basic feature. As for the evaluation of edge detection results, the image edge's virtual reality, direction and positioning are generally considered. Edge detection with high precision and low error rate is the best edge detection method. Canny edge detection is adopted in this paper\(^5\). Canny edge detection operator, in the process of image edge detection, first smoothes the image to reduce the noise, and then the edges of the image are computed using differentiation. The result can suppress the noise well, and the precision of the edge detection result is also higher\(^6\). Canny operator of the maximum inhibition method was applied to image edge extraction, according to the gradient direction, the image gradient as a discrete numerical rules in a certain area, the direction of the edge gradient approximation is divided into horizontal, vertical and diagonal 45 degrees and 135 degrees of four directions, set the center pixel point \(f(x, y)\), the grey value and its value comparison around week, their grey value in the gradient direction is not very big or is zero, the difference between the definition that point value is 0, namely not image edge; Conversely higher gradient brightness may be marginal.

In the process of determining the image edge, a threshold value cannot obtain the complete image edge, and multiple experiments with more than one threshold value are needed to determine the complete image edge. Canny operator edge plus measurement method sets two thresholds \(T_1\) and \(T_2\) when conducting edge detection. Setting \(T_2 = 0.4 T_1\), compared with \(T_1\) first step to make the gradient image value, less than \(T_1\) set of the gray-scale value is 0, after testing all gradient values get image 1. At
this time of image after image edge detection is not complete, continue to use $T_2$ value of image edge detection, the process is similar. If the image of gradient value is higher than $T_2$, the output the result, the resulting image 2.

Image 1 and image 2 are not complete images after edge detection. Image 1 cannot effectively reduce noise due to the small threshold set during detection, while image 2 can effectively suppress noise, but a lot of edge information is lost due to the large $p(x,y)$ threshold set. Based on this, image 1 $q(x,y)$ can be combined with image 2, and image 2 can be taken as the basis to mark the first pixel whose gray value is not 0. Find the point of connection of contour line all the non zero, for the last little tag, and then find the corresponding points in images 1, within the neighborhood in the image 1 the value of the test, the grey value of zero points added to the image on the corresponding position of 2 tag $t(x,y)$ as the and its as the starting point, to continue the operation, until the circulation can't go on. The contour to be detected is marked, and all undetected contours are detected until all contour detection is completed.

5. ANALYSIS OF SCATTERING FEATURE RECOGNITION TEST

5.1. A simulation test device for car crash debris

Due to the limitation of conditions, the actual crash test cannot be carried out. According to the similarity theory and relevant regulations, the test meets the national requirements for automobile crash test on the basis of minimizing the cost. In the collision test, the external dimension ratio of test vehicle and real vehicle is 1:5. The situation of the scattered materials in the accident site after the collision of the test vehicle with the fixed obstacle and another test vehicle at different speeds. The calculated results can be used to solve the collision speed when the accident happens.

The test equipment for simulation test of vehicle collision and scattering objects mainly includes collision trolley, fixed obstacle, three-phase asynchronous motor, roller and roller support, safety rope, belt, frequency converter and radar speedometer, etc. Test vehicle 1 was used to simulate the scene of the accident and obtain different images of scattered objects in the scene of the accident. Test vehicle 1 is mainly composed of frame, bumper, cab, container and container support. In the test, two cars are involved in the forward collision. Test car 2 is designed, whose size is 70% of that of the collision car. The specific dimensions are shown in Table 1.

| TABLE 1. DIMENSIONS OF COLLISION CAR |
|--------------------------------------|
| Car length/m | Car width/mm | Car height/mm | Cargo box length/mm | Cargo box width/mm | Container height/mm | Front overhang/mm | Back overhang/mm | Wheelbase/mm |
| Test car 1   | 1199         | 430           | 464              | 846                | 430                | 30               | 219             | 308           | 672          |
| Test car 2   | 840          | 301           | 348              | 592                | 301                | 30               | 153             | 216           | 470          |

The physical map of the designed collision car is shown in Fig. 5.

![Figure 5. The physical object of the collision car](image)

The work of the three-phase AC motor is to make the colliding trolley collide with the fixed barrier wall or the colliding trolley by pulling the rope. In the experiment, with wire will crash the car, length is
2 m of the elastic belt, safety rope of Φ= 8 mm and 15 kg standard weight firmly together, when the car collision with the obstacles or touch the collision of the car is not in the preset position, safety rope and elastic belt can pass the weight of sliding work to reduce the car collision speed or stop, in order to reduce risk. Since the maximum speed of the colliding car is 50 km/h, the colliding car can be stopped when the heavy block slides 6.18 meters on the ground under the maximum speed, so the test setting meets the requirements.

5.2. Verification of scattering feature recognition test in simulated collision test.
According to the test scheme, the simulation test of car collision scattering objects was carried out to obtain the scattering objects images at the accident scene. According to the shape of the scattering objects, the camera calibration system was used to shoot. The distance between the camera center and the ground was 140mm. The calibration objects in the image were identified. Otsu algorithm was applied to binarization operation of the image. The image noise was removed by means of expansion and corrosion. The result is shown in Fig. 7.

The length of the minimum enclosing rectangle of the calibration object is denoted as LenP in pixels, while the actual length of the calibration object is denoted as Len in cm. According to the known conditions, the value of Len is 23 cm. According to \( r = \frac{\text{Len}}{\text{LenP}} \), the relationship between the actual value of feature information in the image and the pixel value can be determined. MATLAB software was used for image pretreatment, including gray enhancement, binarization, Wiener filtering, etc. Bwareaopen function was used to remove the useless information, and the pre-processed image was shown in Fig. 8. After identifying the calibration objects to determine the proportional relationship between the image pixel value and the actual value, the image features of the scattered objects are identified and extracted. In Figure 9, the scattered objects are mainly circular objects and rectangular boxes. For the recognition of the circular objects, the regionprops function can be applied to identify their area and the diameter by the function Major Axis Length. For cuboid box, it can be obtained by extracting coordinate points for calculation. The final image is shown in Fig. 9.

Two-car collision is also a common type of accident. In the designed car collision and scattered object simulation test, the simulation test of two-car collision is carried out. By changing the parameters of the frequency converter to adjust the motor speed, the motor drives a small car to move at a certain speed and collide with another stationary car. The frequency of the frequency converter is set as 15Hz, that is, the driving speed of the moving car is 19 km/h. After the collision, the scene of the stationary car and some important scattered objects is shown in Figure 10. After the collision, the position of the stationary car changed. The image shows that the car can be regarded as one of the scattered objects at the accident site. MATLAB is used for image processing to identify the shape and size of the car and other scattered objects to solve the vehicle. The speed at the time of the collision provides a certain basis.
After using the camera calibration system to obtain the scattered object image, first identify the calibration object in the image, and the result is shown in Fig. 11.

![Figure 10. Images of scattered objects at the scene of the accident](image1)

After identifying the calibration objects in the image, apply the method proposed in the article and MATLAB programming to identify the features of the scattered objects in the image. In order to improve the accuracy of feature recognition, first perform operations such as preprocessing of the image, Canny edge detection, etc. According to the correlation function or parameters determine the shape and size of the scattered objects, and the final recognition image is shown in Fig. 12.

![Figure 11. Final recognition result image](image2)

Fig. 12 shows the shape and size of the scattered objects in the accident scene. The car is simplified as a rectangular object in the figure, and the length and width of the rectangle are identified as the features of the car to obtain the size of the final target object.

5.3. Analysis of image feature recognition results of scattered objects

After the application of MATLAB processing, the size unit of the target object is pixel, the size unit needs to be converted to mm to compare with the real size. The calibration system proposed in the paper is applied to achieve proportional conversion with MATLAB programming. Table 2 shows the result of conversion of image pixel value to value in mm.
TABLE 2. IMAGE PIXEL VALUE CONVERSION

| Target object | Object 1 | Object 2 | Object 3 | Object 4 | Object 5 |
|---------------|----------|----------|----------|----------|----------|
| Object pixel value (pixel) | 141 | 474*73 | 702*65 | 133 | 148 |
| Calculation result (mm) | 58.52 | 196.72*30.35 | 291.31*27.0 | 55.83 | 61.67 |

By comparing the converted result with the actual measurement size, the error obtained is shown in Table 3.

TABLE 3. ANALYSIS ERROR

| Target object | Object 1 | Object 2 | Object 3 | Object 4 | Object 5 |
|---------------|----------|----------|----------|----------|----------|
| MATLAB calculation results (mm) | 58.52 | 196.72*3 | 291.31*27.0 | 55.83 | 61.67 |
| Actual size of object (mm) | 62.00 | 185.00*3 | 270.00*30.0 | 62.00 | 62.00 |
| error% | 5.61 | 5.73 | 7.71 | 9.95 | 0.53 |

It can be seen from Table 3 that, for Fig.9, after image processing by MATLAB, the results obtained after object size conversion are compared with the actual measurement results, and the error range is 0.53%~9.95%, within the allowable error range. The feasibility of the calibration system and the image processing program is verified. For Fig.12, Table 4 shows the result of converting the image pixel value to the value in mm. Compare the MATLAB calculation results with the actual measurement results, as shown in Table 5.

TABLE 4. IMAGE PIXEL VALUE CONVERSION

| Target object | Object 1 | Object 2 | Object 3 | Object 4 | Object 5 | Object 6 | Object 7 |
|---------------|----------|----------|----------|----------|----------|----------|----------|
| Object pixel value (pixel) result (mm) | 119 | 121 | 72 | 128 | 606*42 | 1889*671 | 440*190 |
| 55.61 | 56.51 | 33.64 | 59.78 | 283.71*26.39 | 882.21*313.40 | 205.52*88.73 |

TABLE 5. ERROR ANALYSIS OF RESULTS

| Target object | Object 1 | Object 2 | Object 3 | Object 4 | Object 5 | Object 6 | Object 7 |
|---------------|----------|----------|----------|----------|----------|----------|----------|
| MATLAB calculation results (mm) | 55.61 | 56.51 | 33.64 | 59.78 | 283.71*26.39 | 882.21*313.40 | 205.52*88.73 |
| Actual size (mm) | 62.00 | 62.00 | 40.00 | 62.00 | 270.00*30.00 | 950.00*322.00 | 185.00*95.00 |
| error% | 10.31 | 8.85 | 13.59 | 3.58 | 4.90 | 6.59 | 7.64 |
As can be seen from Table 5, the error range is concentrated in 3.58%~10.31%. Within the allowable range, the error of object 3 is 13.59%. The reason is that the object is relatively small and the camera height is high when shooting, resulting in a certain depth error. Based on this, the error can be reduced by reducing the shooting height or using a more accurate camera. In general, the results of object calculation can meet the requirements of feature recognition of scattering objects in the accident scene, and can be brought into the scattering object throwing distance model to solve the collision speed.

6. CONCLUSION
In this paper, the object of study is the scattered objects in the traffic accident scene, and a camera calibration system is established to obtain the scattered objects in the traffic accident scene. Wiener filter denoising and Laplacian sharpening are used to preprocess the image. Canny operator edge detection is used to determine the scattering object recognition formula. The simulation test of car collision scattering objects is designed, and the characteristics of scattering objects are identified by MATLAB. The dimensions of the minimum enclosing rectangles of circular, rectangular and irregular objects are calculated and compared with the actual dimensions. The error is concentrated in 0.53%~10.31%, which is within the allowable range, which verifies the accuracy and applicability of the calculation results. This method can be used to obtain the characteristics of scattered objects in the accident site, and obtain other information such as the solution of collision speed in the next step of the accident site, so as to provide a certain basis for the further treatment of the accident site.

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