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Research in Algorithm of Image Processing Used in Collision Avoidance Systems

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Abstract: With the rapid development of Intelligent Vehicle System (IVS) method, its research involves different kind of fields, such as computer measurement, control method, computer vision method, sensor data fusion method and vehicle project. In order to control the vehicle automatically only based on the images, we use some special technique of image processing method to extract the feature of the images, the process is complicated, it involves three steps. The paper first introduces image processing method, the technology and its application, then the paper focus on collision avoidance system to explain why image processing is important to it. What is more, the paper mainly explain algorithm of image processing, include image enhancement, detection algorithm of image edge, fast inverse transform algorithm based on characteristic curve. Finally, the paper gives an example how these image processing applies in road scene and its effectiveness. *Copyright © 2013 IFSA.*

Keywords: Collision avoidance system, Digital image, Image enhancement, CF-IHT algorithm.

1. Introduction

The computer image processing could convert an image signal into a digital signal to be processed by computer [1]. Since computer processing is fast, and the digital signal have little distortion, easy to store and transport with strong anti-interference ability and other characteristics, computer image processing is widely used in many major areas. Digital image tamper detection is done by analyzing statistical properties of the image contents of the authenticity of the digital image, scene authenticity and integrity of authentication methods, namely whether the image is the original image, the image is real and whether they contain other secret information images, these technologies is the digital image forensics [2]. The image processing includes the following aspects: first, image to digital conversion and the associated image restoration; second, geometric transplant, such as translation, rotation; third, modeling; fourth, line color control; fifth, the use of curves, and surfaces; sixth, the transformation between color [3].

Computer image processing technology can be applied in the agro-processing, with such technology it will achieve the goal harvesting or processing of agricultural products automation and reducing manpower burden, for example, mushroom picking automation system and shrimp processing operation control system. Computer image processing technology can also be applied in the industrial production automation [4, 5]. For example in the industrial production automation, configuration diagram of some machines and related parts and the production line identification system device use computer image processing techniques to identify the relevant system configuration process, and transmit accurate control or the desired structure to the machine control system or robot, in order to achieve automation of production lines [6]. Computer image processing technology can be applied in road traffic which is named as road traffic camera monitoring system. Computer image processing technology can also be applied combining with remote sensing technology [7]. Computer image processing technology can also be used in engineering design drawings, information conversion process. The common image processing method is electrical analog processing technology and Optical - computer processing technology. Electrical analog processing technology could convert the light intensity signal into an electrical signal, and then use the electronics to deal with the signal such as add, subtract, multiply, divide, split the concentration, contrast amplification, color synthesis, spectroscopic contrast and so on [8-10].

Image processing techniques include image compression, image enhancement and restoration, image matching, description and identification. In order to improve the picture quality, picture image enhancement is needed, such as increasing contrast degree, geometric distortion correction and so on. Image enhancement methods can be divided as frequency domain method and the spatial domain method [11]. Low-pass filtering can remove noise in the image; high-pass filtering can enhance the edges and other high-frequency signal, so the picture becomes clear. Image restoration is a technology used when the image is blur or with noise, to estimate the original image [12]. Image matching, description and recognition is the main purpose of image processing, which is to obtain an image with a clear sense of images or graphic made up with values or symbols instead of document which is randomly distributed. In this paper, digital image forensics certification of the authenticity of the natural scene images and computer-generated image detection research was demonstrated.

2. Collision Avoidance System

2.1. The Consists of Automotive Collision Avoidance System

Automotive collision avoidance system is consists of three parts. The signal acquisition system: use radar, laser, sonar and other technology to automatically detect the vehicle speed, speed of vehicle before and the distance between two vehicles. Data processing systems: computer chips processed the information for two cars instantaneous distance and relative speed of the two vehicles to determine a safe distance between the two vehicles, if the distance is less than safe distance, data processing system will issue commands. Implementing agency: responsible for conducting the command from the data processing system, make an alarm to alert the driver brakes, if the driver is not executing instructions, the implementing agencies will take measures, such as closing windows, adjust the seat position, lock the steering wheel, automatic brakes.

2.2. Spatial Domain Processing

In image feature extraction technology, the edge information is a very important feature. Image sharpening technology is a very effective image edge enhancement technology. The image is the high frequency part of the image. In the spatial domain processing, image sharpening technology is the same way as image smoothing technology, to convolution of impulse response of image and the filter.

In the intelligent vehicle system, preventing vehicle collisions from obstacles on the road is an important factor to ensure traffic safety, collision avoidance systems in intelligent vehicle system is of great importance. When we drove, we received information are almost all from the vision. When we drove, we received information are almost all from the vision. Traffic signals, traffic patterns, road signs and so on can be seen as a visual communication language between environment and the driver. Computer vision mainly plays the role of environmental detection and identification in intelligent vehicle collision avoidance system studies.

Compared with other sensors, machine vision has advantages like large amount of detected information and being able to detect information far away, its disadvantage is that when in a complex environment, extracting the target and background detected, requires a large amount of computation. If you just want to solve the problem under the current hardware conditions, it is easy to lead to poor real-time system. In intelligent vehicle collision avoidance system, the computer vision plays a very important role, it is one type of the most important sensors. It is the image processing technology that enables operation of this sensor, if there is no effective image processing techniques, the automatic control of the whole system will fail, not even achieve the purpose of automatic avoiding vehicle crash.

3. Algorithm of Image Processing

3.1. Natural Image Formation Mechanism

A digital camera was a fashion digital product, with its powerful function, easy operation and excellent shooting, by the majority of consumers. CFA color filter array is determined by the color filter array is inlaid, each pixel location in one color only allowed through, blocking the other two frequencies of color through. The color filter array of the CFA was shown in Fig. 1. Application of the CFA color image sensor array, must apply to the interpolation pixel value obtained obtained in the three primary colors at each pixel location information, the resulting color values are generally also for color correction and white balance operations. In order to enhance the visual effect of the digital image, the image sensor must also be a linear response, and the core filter to be adjusted, the image processing further comprises an additional gamma correction.

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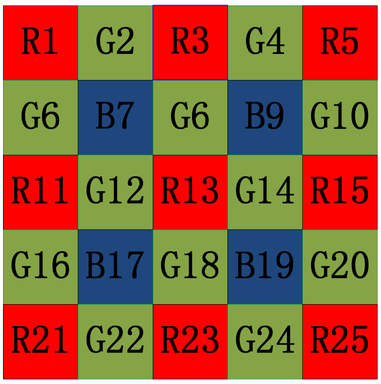

Fig. 1 The color filter array of the CFA.

3.2. Gray Value Trimming of Image Pixel

Gray value trimming of the image is a simple and effective enhancement operation. It is mainly in two forms: one is the gray value correction, to modify the individual image pixel gray level to compensate for the uneven exposure of the original recorded image; another form is gray value mapping transformation, which aims to use uniform approach to change the whole image grayscale or change some gray areas of the image in order to increase the contrast degree, making image details more visible. If set the original gray domain of $f(x, y)$ is $[a, b]$, after liner transforming, the gray domain of $f'(x, y)$ is $[a', b']$, the relationship between $f(x, y)$ and $f'(x, y)$ is:

$$f'(x, y) = a' + (b' - a')/(b - a)(f(x, y) - a) \quad (1)$$

Fig. 2 and Fig. 3 show an example of a standard image of rice and image whose contrast degree enhanced through the gradation value linear transformation. From subjective evaluation and histogram, it can be seen in after transformation the contrast of gray values increase, thus emphasizing the details of the original image to get better edge detection results.

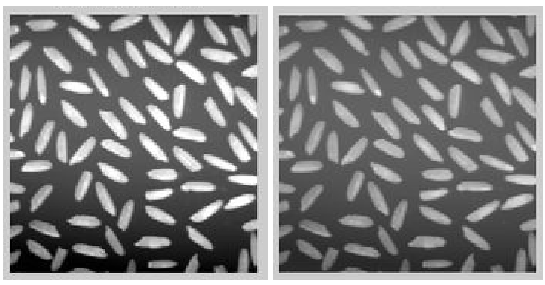

Fig. 2. The original image of rice and image after transformation.

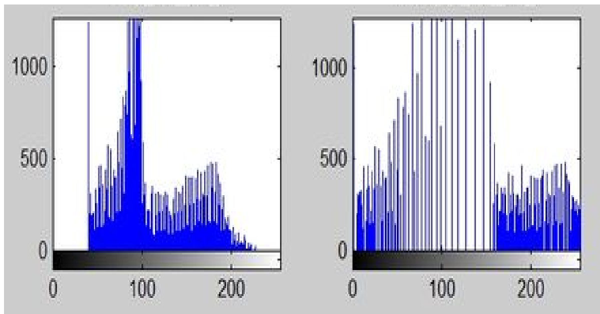

Fig. 3. Contrast of gray values.

3.3. Frequency Domain Processing

Signal, as a two-dimensional image, can be mapped to the transform domain as same as the one-dimensional signal by the Fourier transform method, in which the transform coefficients reflects the characteristics of the image. Frequency domain processing is a technique to modify each frequency band of Fourier spectrum of the image at different degree, based on certain image model. Structure diagram of frequency domain processing system was show in Fig. 4.

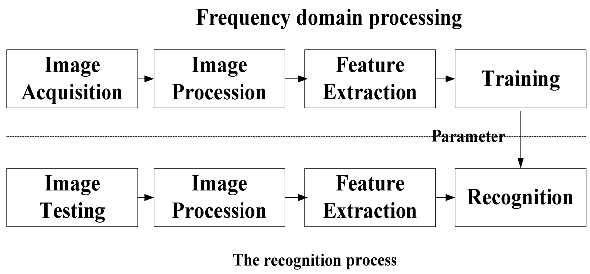

Fig. 4. Structure diagram of image processing system.

Intrinsic properties of transform domain is often used in image enhancement, for example, make a low pass filter to let low frequency components pass and effectively prevent high frequency components, which means filtering noise of high frequency in the frequency domain, and then through inverse transform you can get smoother images.

3.4. Detection Algorithm of Image Edge

The image edge is a collection of pixels whose surrounding pixel with a step change or roof in gray variation. Edge exists widely between object and background between objects. One is step edge, between adjacent areas of two different gray values in the image. Another edge is the roof-shaped, which is located in turning point of gray value. For the step edge, the second derivative at the edges is zero crossing; for the roof-like edge, the second derivative at the edges is of the extreme value. Derivative operators could emphasis on gray change, if derivative operator is used, the value is higher at pixel with large gray changes. So you can set the derivative values as edge intensity of the corresponding pixels, by setting the threshold value to extract the edge pixels. The paper uses LOG operator, it is:

$$\nabla^2 g=\nabla^2[h(x,y)*f(x,y)]=((r^2-\sigma^2)/\sigma^4)\exp(-r^2/2\sigma^2)*f(x,y) \quad (2)$$

Through the nature when second-order derivative operator is at zero point, it will determine the locations of the image ladder-like edge. The edge detection algorithm of Log operator is as follows:

Obtain filtered image with Laplacian-Gauss filter for image filtering. Do zero-crossing detection for the image obtained: assume that the pixel of first-order differential image is $P(i, j)$, $L(i, j)$ is its Laplace value. Determine in accordance with the following rules: if $L(i, j) = 0$, we could conclude whether $(L(i-1, j), (i+1, j))$ or $(L(i, j-1), (i, j+1))$ contains two number with opposite sign. As long as one of these two number couples contains two numbers with the opposite sign, then $P(i, j)$ cross zero. And if the first-order difference value of $P(i, j)$ is greater than a certain threshold, $P(i, j)$ is an edge point, otherwise not. If $L(i,j) \neq 0$, then determine four number couples

$$(L(i,j),(i-1,j)),(L(i,j),(i+1,j)),(L(i,j),(i,j-1)),(L(i,j),(i,j+1)) \quad (3)$$

contains two numbers with opposite sign, if do, point besides $P(i, j)$ cross zero, and if the first-order difference value of $P(i, j)$ is greater than a certain threshold, $P(i, j)$ is an edge point, otherwise not.

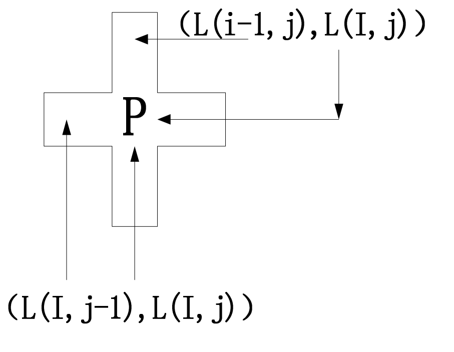

Fig. 5. The detection algorithm of Log operator.

Do experiment for log operator in the case without noise pollution, with Gaussian noise, with pepper noise, with multiplicative noise, the Log operator image edge detection has good detection results in the above three noise situation. Therefore, we use log operator edge detection algorithm in subsequent experiments as the image edge detection method. The detection algorithm of Log operator was shown in Fig. 5.

3.5. Fast inverse Hough Transform Algorithm Based on Characteristic Curve

Boundary tracking, also known as the edge point linking, search from an edge point in edge gradient map to the adjacent edge points so as to gradually approach the detected boundary. Follow the principle of the boundary tracking to look for "growth point", based on some characteristic curves detected, such as the slope of the line, the origin of the circle, the radius, the curve equation and so on, according to the Hough inverse transform reconstruction criteria to determine whether the reconstruct these "growing point". If they meet the conditions for reconstruction, then this "growth points" would be reconstructed. Then set these "growth points" as "feature points" for a new round of the reconstruction to find new "growth points", until it reaches the pre-established testing standards.

(a) Initialize the reconstructed image $A-inv$:set all elements of matrix $A-inv(M \times N)$ as 0.

(b) Choose feature point: the number of feature point of original image is n.

(c) Reconstruct feature point: set feature point (x_i, y_i) and $A(x_i, y_i) = 0$, then set inverse transform as left part and right part, then calculate as follows:

If $x_i > y_i$, then

$$\theta = \tan^{-1}(y_i/x_i) \quad (3)$$

$$\theta_1 = \theta * s\theta \quad (4)$$

$$\tilde{\theta}_1 = \text{round}(\theta_1) \quad (5)$$

$$\rho_1 = (x_i \cos(\theta_1) + y_i \sin(\theta_1))*s\rho \quad (6)$$

$$\tilde{\rho}_1 = \text{round}((x_i \cos(\theta_1) + y_i \sin(\theta_i))*s\rho \quad (7)$$

$$\Delta\theta = s\rho * \cos^{-1}(\tilde{\rho}_1 - 0.5)/\tilde{\rho}_1) \quad (8)$$

$$\Delta\theta_1 = \text{floor}(\tilde{\theta}_1 - (\theta_1 - \Delta\theta)) \quad (9)$$

Check the point $C(\tilde{\theta}_1 - \Delta\theta_1, \tilde{\rho}_1)$ of Hough parameter space definition matrix $C(\theta(\rho)$, if the value is not zero, that means the curve where the pixel (x_i, y_i) is Hough transform makes a contribution to cumulate $C(\theta(\rho)$, the value of

(x_i, y_i) is 1, then set the value of point corresponding to (x_i, y_i) as 1 in matrix $A\text{-}inv$.

$$A\text{-}inv(x_i, y_i) \leftarrow 1 \quad (10)$$

$$C(\tilde{\theta}_1 - \Delta\theta_1, \tilde{\rho}_1) \leftarrow C(\tilde{\theta}_1 - \Delta\theta_1, \tilde{\rho}_1) - 1 \quad (11)$$

If $x_i < y_i$, (x_i, y_i) belongs to right part, the calculation is similar to left part, but the only difference is :

$$\Delta\tilde{\theta}_r = floor((\theta_1 + \Delta\theta) - \tilde{\theta}_1) \quad (12)$$

Similarly, check $C(\tilde{\theta}_1 + \Delta\theta_r, \tilde{\rho}_1)$ in $C(\theta(\rho)$, reconstruct the point as the above rules.

Search for growth point: according to boundary tracking principle and information of detected curve, search from feature point, and search growth point from these points. Reconstruct growth point: do as step 3, and store the results in reconstructed matrix, $A\text{-}inv$.Repeat search with set the growth point in step 5 as feature point. Repeat step 3 to step 6, until it reaches the pre-established testing standards. Finish recycling.

Software of computer image generation existing can do and natural images are very similar in content, it is in one order and two order statistical feature matching, but in the details of edge three moments like that and four order moments are hard to match. The flowchart of CF-IHT algorithm was shown in Fig. 6. Consider from the point of view of mathematics, the matching of one order and two order statistics are relatively simple, but to achieve three orders or higher order accurate matching is a very difficult task. The flowchart of algorithm is:

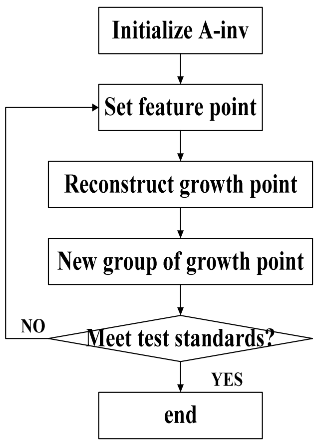

Fig. 6. Flowchart of CF-IHT algorithm.

CF-IHT would select n feature points from the M × N points, then set these feature points as starting points, use some prior information of the curve, according to the method of boundary tracing following a certain direction to search for growth points, which greatly reduces number of detected points, reduce those redundant point unrelated to the detected curve, thus reducing the storage space. In addition, the algorithm repeatedly using the "loop", so that the parameter in the" loop" could reuse their storage space, which means, to some extent, it could solve the problem that the storage space required by the algorithm SIHT is too large. The loop of algorithm also reduces the computational complexity, each pixel could be processed in this loop processing, so that the algorithm structure is simple.

4. Simulation of Road Scene

4.1. Image Enhancement of Road Scene

The result of the experiment shows that, if image has been enhanced, the difference of gray value of the edge of image with other points has been enlarged, when use Log operator to extract image edge, the extraction result is better with image enhancement, the point misjudgment has reduced. The result of image enhancement was shown in Fig. 7.

(a) The original image

(b) The gray scale image.

Fig. 7. The result of image enhancement.

4.2. Image Feature Curve Extraction of Road Scene

Do experiment for the original image with Gaussian noise, with pepper noise, with multiplicative noise, and check if the Log operator image edge detection has good detection results in the above three noise situation. Add pepper noise with density 0.02 to check the results. Salt and pepper noise generated pollution for image which is very similar for rain and snow weather condition, therefore, the ability to adapt to this kind of noise is very important. Image feature curve extraction with different noise was shown in Fig. 8.

(a) The image with pepper noise

(b) The detection result of Log operator

Fig. 8. Image feature curve extraction with different noise.

With the above images, the conclusion can be drawn: Log Operators image still has good noise immunity for a specific scene, the edge detection effect is stable, little affected by noise. Therefore, we use Log Operators image edge detection, to provide binary edge image for subsequent experiments.

4.3. Image Edge Detection of Road Scene

In the image acquisition and transmission process, Gaussian noise is most likely to happen, so we chose an image affected by Gaussian noise do feature extraction experiments. The example of corrosion operation was shown in Fig. 9.

In the experiment, we first through visual sensor to catch an image affected by Gaussian noise, do image enhancement to the image, then we use the Log Operators to make image edge detection, finally use CF-IHT algorithm to extract characteristic curve in binary edge image. The experimental results show that with image enhancement, edge detection and extraction of the characteristic curve of the road scene, road line information of the image can be obtained, to realize intelligent control of the vehicle.

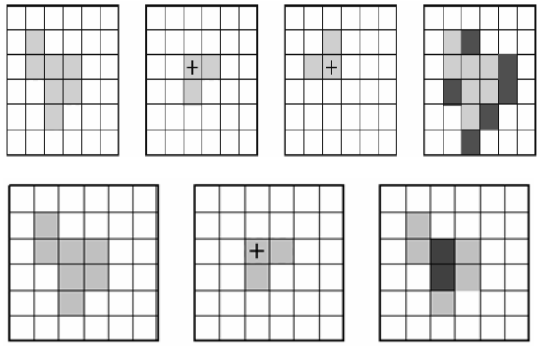

Fig. 9. The example of corrosion operation.

4. Conclusion

The paper is mainly about image processing technology, whose aim is to find a suitable feature extraction algorithm to extract some information form image to support the realization of computer vision collision avoidance systems. Before image feature extraction, image must be disturbed during image collection and transmission. Based on image enhancement, we then conducted image feature extraction. The paper selected the Log operator edge detection algorithm to do edge detection for the original image. The paper then use CF-IHT algorithm to conduct image feature curve extraction, which greatly reduces number of detected points. Finally, we conducted simulation experiments for road scene image, the results showed that, Log operator still has good noise immunity, then we got the binary edge image after feature curve extraction used CF-IHT algorithm to detect road line curve, in order to provide effective control information for computer, and ultimately to realize the image feature extraction purposes.

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