Color and Texture Feature Recognition of Traditional Pen and Ink Painting Based on Visual Sensor

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Abstract

Visual inspection technology testing is an application of machine vision theory. In recent years, this field has become an important and rapidly developing field of instrumentation and engineering research. Based on the vision sensor technology, this paper launches the research on the color and texture feature recognition of pen and ink painting. This article first researches the power supply system and obtains the power supply scheme diagram, and then tests the visual sensor in five steps and appropriately optimizes the parameters. Finally, 6 sets of comparative experiments were carried out, each of which was 100 times to identify the color and texture of the pen-and-ink painting. The experimental results are as follows: the number of successful color recognition is 97, 95, 90, 94, 92, and 96 times, and the number of successful texture recognition is 84, 87, 82, 91, 96, and 97 times.

Keywords: Visual sensor, Traditional pen and ink painting, Color texture, Feature recognition

1 Introduction

As the requirements of industrial control systems for automation and high speed become increasingly important, visual sensors are increasingly accepted as a new type of control system due to their high degree of controllability compared with traditional sensor networks, visual sensor networks pay more attention to the collection and processing of image and video information.

Vision inspection technology is a practical concept of machine vision technology. As the name implies, the audio-visual system is used for "observation" and "measurement" in actual production, with moderate accuracy and noncontact measurement. The pros and cons of the image information collected by the sensor and the segmentation effect of the target object directly determine the pros and cons of a recognition system.

Regarding the vision, sensor, related scientists have done the following research. Neuromorphic vision sensors only transmit local pixel-level changes caused by blinking when blinking occurs, which results in advantageous characteristics such as ultra-low latency response. Chen first proposed a set of effective biological characteristics, based on the microsecond time resolution of event density to describe the motion, speed, energy, and frequency signals of blinking, then uses the neuro-biometric data set, training integrated model and the nonintegrated model for biometric authentication. Experiments show that the system can identify and verify the subject with an accuracy of 0.948 and an accuracy of 0.925 for the nonintegrated model [1]. Pan proposed a new high-precision image deviation correction method for the line structured light vision sensor. The mathematical solution of the position uncertainty of the stripe point is proposed, and the position uncertainty of the target feature point and the stripe point is established [2]. Dong S proposes a collaborative drone navigation algorithm that allows the main aircraft (equipped with inertial and visual sensors, GPS receivers, and vision systems) to improve its navigation performance (real-time or in the postprocessing stage), using the self-equipped sight measurement of the formation flying deputy of the GPS receiver. The analysis shows the potential of the developed method, mainly due to the possibility of using precise magnetic and inertial independent information [3]. These methods have provided some references for our research, but due to the short time and small sample size of the relevant research, the research has not been recognized by the public.

The innovation of this paper is to introduce visual sensor technology to calculate the cross entropy, average absolute error, mean square error, signal-to-noise ratio and peak signal-to-noise ratio between the fusion image generated by the average method and the multiimage fusion method and the original image. The visual sensor recognition steps are divided into five specific stages, the parameters of the visual sensor are appropriately optimized, and the group comparison experiment is carried out, and the experimental results are obtained.

2 Traditional Pen and Ink Painting Color and Texture Feature Recognition Method

2.1 Vision Sensor

Vision sensors are the direct source of information for all imaging systems, including one or two image monitors, and sometimes a light projector and other accessories [4]. A typical application framework based on vision sensors is shown in Figure 1.

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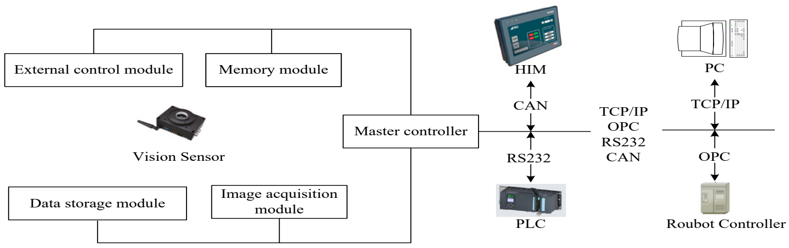

Figure 1. Typical application framework based on vision sensors

The low cost and ease of use of vision sensors have attracted machine designers and process engineers to integrate them into various applications that once relied on manual labor, multiple photoelectric sensors, or no inspection at all. Industrial applications of vision sensors include inspection, metrology, measurement, orientation, defect detection, and sorting. The following are just some application examples:

In the automobile assembly plant, it is checked whether the glue beads applied by the robot to the door frame are continuous and have the correct width. In the bottling plant, verify that the cap is properly sealed, the filling level is correct, and that no foreign objects fall into the bottle before capping.

In the packaging production line, make sure to paste the correct packaging label at the correct position.

The vision sensor has thousands of pixels and can capture light from all images. The clarity and beauty of an image are usually expressed in pixels, and some video sensors can capture 1.3 million pixels. [5]. Figure 2 shows the working system model of the general vision sensor.

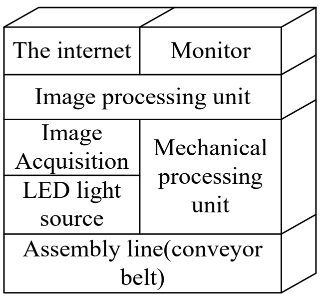

Figure 2. General vision sensor working system model

Image acquisition is an indispensable part of vision sensors. Because different detection targets also have different requirements for the collected images, mainly the field of view, resolution, speed, and so on. For a 5mm×5mm component, if the detection accuracy is to reach 0.01mm, for a single-pixel precision detection algorithm, a resolution of at least 500×500 is required.

The most basic principle of a typical passive vision sensor is based on the stereo parallax method. Starting from the human binocular imaging mechanism, this method uses two or more cameras with fixed positions to obtain two or more images of the same scene by fully utilizing the existing non-structured light lighting conditions.

The active vision sensor uses structured light illumination. By projecting a specific structured light to the three-dimensional scene to be reconstructed, the surface of the three-dimensional scene modulates the space or time of the structured light field, then the observed light field carries the information of the three-dimensional surface, and the three-dimensional surface data can be obtained by demodulating the light field. Based on different measurement principles, it can be further subdivided into several types of active vision sensors.

Active sensors are mainly divided into the following two types:

(1) Active vision sensor based on the triangle principle. This form of sensor uses the geometric structure information provided by a special light source to help extract the three-dimensional coordinate information of the surface of the object.

(2) Active vision sensor based on the principle of phase measurement. Satisfactory results are obtained by using a phase interferometer for three-dimensional measurement. The object surface depth information is obtained from the relationship between the phase change of the interference fringes projected on the object surface and the object depth.

Computer vision combines image processing, pattern recognition, and artificial intelligence technology, focusing on computer analysis of one or more images. The image can be acquired by single or multiple vision sensors, or a sequence of images acquired by a single sensor at different times.

Feature-based image registration has the characteristics of good robustness and low computational complexity. The specific formula is as follows:

$$f_{CRF} = \left\{ \begin{matrix} 0, |P(x) - P(m) \le \alpha_1| \\ 1, |P(x) - P(m) \ge \alpha_1| \end{matrix} \right\}. \quad \textbf{(1)}$$

$$T = \sum_{x \in circle(c)} f_{CRF}(x, m). \quad \textbf{(2)}$$

$$U_s = \min\{Dist(U_r, U_k) \mid U_k \in B, k = 1, 2, \cdots, m\}. \quad \textbf{(3)}$$

$$U_{\tilde{s}} = \min\{Dist(U_r, U_k) \mid U_k \in B, k = 1, 2, \cdots, m, U_k \ne U_s\}. \quad \textbf{(4)}$$

$P(m)$ — The gray value of the center pixel

$P(x)$ — The gray value of any point on the circular area

α_1 — The threshold of the difference in gray value

The oFAST feature points are finally obtained, and the calculation process is as follows:

$$l_{p,q} = \sum_{x,y \in u} x^p y^q P(x, y). \quad \textbf{(5)}$$

$$R = (R_x, R_y) = \left(\frac{I_0}{I_0}, \frac{I_0}{I_0}\right). \quad (6)$$

$$\omega = \arctan\left(\frac{R_y}{R_x}\right) = \arctan\left(\frac{I_0}{I_0}\right). \quad (7)$$

$$O = \frac{Dist(U_r, U_s)}{Dist(U_r, U_{\tilde{s}})}. \quad (8)$$

$P(x, y)$ is the gray value of point (x, y)

Comparing the gray values of two points within a pixel point pair through the binary test criterion:

$$\mu(p; t_1, t_2)\begin{Bmatrix} 0, otherwide \\ 1, if P(t_1) < P(t_2) \end{Bmatrix}. \quad (9)$$

$$\overline{R}(x_0, y_0) = \frac{1}{num} \sum_{(x,y)\in m_0} R(x, y). \quad (10)$$

$$\overline{R}(x_0, y_0) = \frac{1}{\sum_{(x,y)\in m_0} \alpha(x, y)} \sum_{(x,y)\in m_0} \alpha(x, y) R(x, y). \quad (11)$$

$$\alpha(x, y) = \frac{1}{\sqrt{(x - x_0)^2} + \sqrt{(y - y_0)^2}}. \quad (12)$$

$P(t_1)$-The gray value of the pixel corresponding to pixel block p at position t_1

$P(t_2)$-The gray value of the pixel corresponding to pixel block p at position t_2

Selecting n pixel point pair to generate a n-dimensional binary string vector, which can be expressed as:

$$f(p) = \sum_{\substack{1\le i\le n \\ t_1, t_2 \in p}} \mu(p; t_1, t_2). \quad (13)$$

$$Q = \begin{pmatrix} x_1, x_2, \cdots, x_n \\ y_1, y_2, \cdots, y_n \end{pmatrix}. \quad (14)$$

$$\alpha(x, y) = \frac{1}{2\pi\delta^2} e^{-\frac{(x-x_0)^2 + (y-y_0)^2}{2\delta^2}}. \quad (15)$$

$$\alpha(x, y) = e^{-\frac{(x-x_0)^2 + (y-y_0)^2}{2\delta_D^2}} \times e^{-\frac{(i(x,y) - i(x_0, y_0))^2}{2\delta_R^2}}. \quad (16)$$

$\alpha(x, y)$-Weight

Then use the affine transformation matrix R_θ determined by the main direction θ to rotate M to obtain a new directed description matrix:

$$M_\theta = R_\theta M = \begin{pmatrix} \cos\theta, \sin\theta \\ -\sin\theta, \cos\theta \end{pmatrix} \begin{pmatrix} x_1, x_2, \cdots, x_n \\ y_1, y_2, \cdots, y_n \end{pmatrix}. \quad (17)$$

$$\lambda_\theta(p, \theta) = f_n(p) \mid (x_1, y_1) \in M_\theta. \quad (18)$$

$$Q = \rho m^T G. \quad (19)$$

$$V_p = V_{env} K_{pl} + V_d K_{pl} \cos\theta + V_d K_p (\cos\beta)^n. \quad (20)$$

ρ — The reflection coefficient of the surface of the object

m — The direction of the normal vector on the surface of the object

G — The direction of the incident light shining on the surface of the object

V_{env} — Ambient light intensity

V_d — Intensity of the light source

V_{pd} — Diffuse reflection light intensity of the light source illuminating the point

The line structured light vision sensor projects a piece of laser beam from the line light source to the surface of the object to be measured, forming a projected bright line on it. Due to the modulation of the surface profile information of the object, the bright line will be deformed. The coordinates of the contour on the light profile of the measured object can be obtained by calculating the coordinates of the bright line image on the image surface. The relative positional relationship between the light plane formed by the projector in the line structured light vision sensor and the camera can be obtained by accurate calibration in advance. In the actual measurement, the light plane intersects the object surface to form a light bar.

Intelligent vision sensors have the following advantages:

(1) Multiple sensors execute measurement tasks in parallel, which improves the overall measurement speed of the system.

(2) The image of the point to be measured is processed by the sensor after the image is collected, which avoids the image quality degradation or instability caused by the long-distance transmission of the analog video signal in the industrial field, and improves the measurement accuracy of the system.

(3) The use of a video decoding chip and CPU video interface to complete the decoding and acquisition of analog mixed video signals, replacing the expensive PCI image acquisition card and third-party image acquisition software, reducing system costs.

(4) The TCP protocol is adopted as the control bus protocol, which improves the reliability of the system and the data transmission speed.

The structured light sensor systematically receives light based on the principle of active visual recognition. The auxiliary light source is used to illuminate the surface of the object to be measured, and form a light beam projected by the sensor on the surface of the object to be measured to obtain information such as the size of the object to be measured. According to various structured light sensor designs, the most commonly used structured light sensors are structured light sensors, linear structured light sensors, and multiline structured light sensors [6]. As shown in Figure 3:

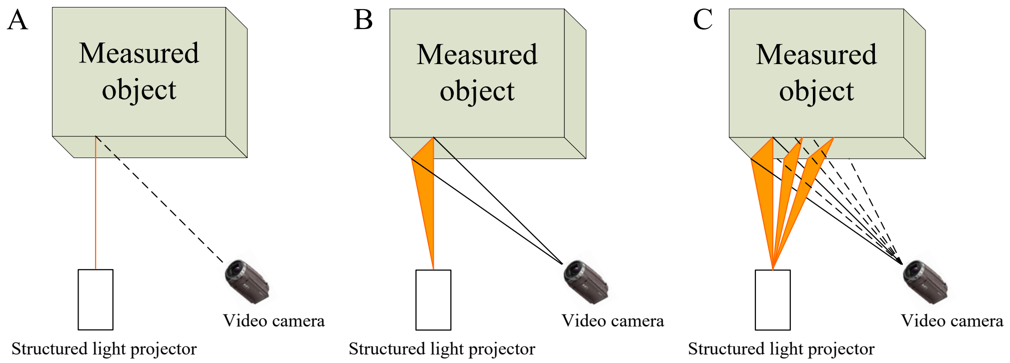

Figure 3. Sensor structure diagram

2.2 Image Features

Image features are often used for image analysis and recognition because they can express the image perfectly. There are many types of image features, most of which can be distinguished by the naked eye, and many of them require image processing. Through the extraction of image features, people can quantify various attributes of the image and express the entire image in the form of numerical values, which can be used as important evidence in image analysis and recognition [7].

The features of digital images can be broadly divided into two categories: global features and local features. Global feature is to construct image features by considering the overall information of the image; while the local feature is just the opposite, it mainly considers the information of a specific local subimage of the image, and constructs a series of local features to jointly represent the image.

Texture features are visual features that reflect the uniformity of an image. Texture feature is a measure of the ratio of pixels to area, and its essence is to describe the gray distribution of pixels. Texture-based methods usually use low-level graphical structural features (such as edges and angles) to define text fields.

Template matching algorithm is a simple and effective recognition algorithm. The basic principle of the tracking system based on the template matching algorithm is to first use the prediction algorithm to predict the trajectory of the moving target after obtaining the target template, and then use the template matching algorithm to locate the precise position of the target. The basic process is shown in Figure 4.

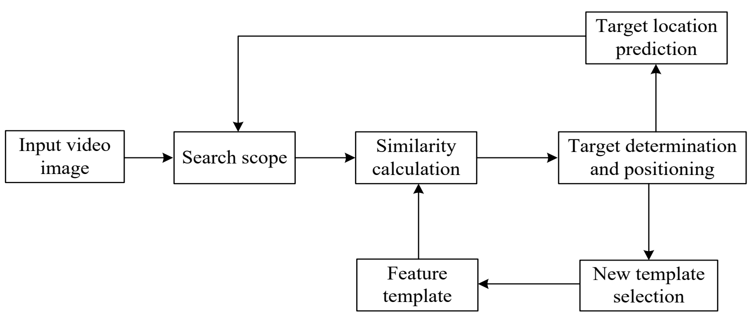

Figure 4. Template matching tracking algorithm flow chart

Color feature is the most basic high-level semantic feature of an image. Because it has high robustness and can be directly obtained from the image, the tracking speed of the target recognition and tracking algorithm based on color feature is faster. In this paper, RGB color features are used as target features to design target recognition based on color features [8].

The images collected by the image acquisition device are basically stored in RGB format. As shown in Figure 5 is the RGB color cube.

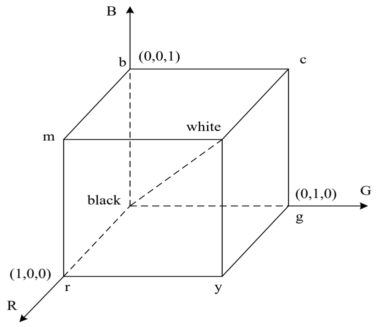

Figure 5. RGB color cube

2.3 Color and Texture Recognition

Theoretically, the error caused using actual colors when distinguishing color attributes is the smallest. However, the human eye is immune to changes in a specific color gamut. Therefore, colors within a certain range can be classified according to the human eye's ability to distinguish colors, and they have the same or substantially the same color in the human eye [9].

Texture is also a essential visual feature of an image. It basically refers to the uniformity of the image, describes the spatial distribution of pixels in a grayscale image, and emphasizes the details of the scene and objects in the image or texture image. The available texture feature recognition methods can be roughly divided into three categories: statistical methods, structural methods, and model methods, but this classification method is not complete, and there are similarities between the methods.

(1) Statistical method. The statistical method is based on the pixel and its surrounding environment, inspecting the statistical characteristics of a specific area of the image, and extracting some statistical data from the gray-scale pixel data to reflect the spatial distribution characteristics of the image texture.

(2) Structural law. The structural approach involves dividing the texture into texture primitives that can be arranged and combined in a certain way. Then, the main task will be to analyze the identification and regulation rules of organizational primitives. Usually, it calculates the texture attribute value of each pixel by comparing the ratio of gray pixels to adjacent pixels, and then determines the texture primitives and their placement rules.

(3) Model method. The model method assumes that the texture distribution of the image matches the given model. The model is first calibrated, and then the corresponding parameters in the model are statistically determined by analyzing the texture of a large number of images, and the model with defined parameter values is used as the acquisition object [10].

3 Traditional Pen and Ink Painting Color and Texture Feature Recognition Experiment

For the visual inspection of large and complex parts, multivision sensor coordinate measurement systems are often used. Due to the limitation of the measurement range of the vision sensor, each sensor only completes the coordinate data measurement of the local feature area of the measured object.

The power supply system is the basis for the stable operation of the electronic system, and the correct distribution of the power supply is especially important for long-term trouble-free operation. Integrated vision sensors are used in industrial facilities, and the sensor power is distributed to the control cabinet through a 24 V DC power supply [11]. Table 1 shows the voltage that needs to be generated.

The system power supply scheme diagram is shown in Figure 6. To improve the power supply efficiency of the power supply system, the overall design principle is to use DCDC to provide high current power supply and use LDO for low current conversion.

Table 1. System voltage

Voltage network label	Voltage value	Voltage signal description
VDDARM	1.2V	ARM processor core power supply
VDDIO	3.5V	On-chip IO subsystem power supply
VDDINT	1.2V	CPU interrupt, controlled by CPU
VDDALIVE	1.5V	CPU life voltage
VDDPLL	1.8V	Phase-locked loop power supply, controlled by CPU
VDDMEM	2V	MDDR chip, CPU memory interface power supply
VDDDEV	3.3V	Power supply for Flash and other chips of the system

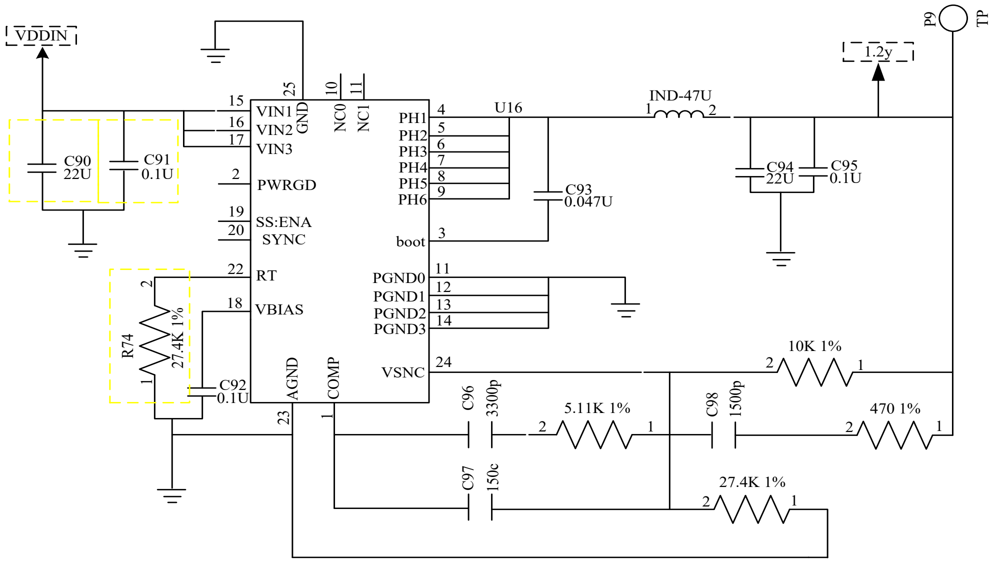

Figure 6. Core 1.2V power supply circuit

Among them, ΔV is the ripple voltage taking 20mV, and the multiplier 2 represents the capacitance drop caused by the DC bias voltage. The calculated minimum capacitance value is 6.25uF. Choose a ceramic capacitor with small impedance and volume, with a nominal value of 22uF and withstand voltage value is 16V, 1210 package. C97, C96, and R75 form a current feedback topology network, and C90 and C91 complete the input voltage filtering.

Test vision sensor:

(1) Using a voltmeter to check whether each power supply pin of the unwelded circuit board is short-circuited to the ground reference; whether each power supply pin is short-circuited.

(2) The PCB is welded in modules, and the power supply system is the most important link in the entire embedded system. Therefore, first solder power chip, and after the soldering is completed, perform a short circuit and open circuit test on the key points of the circuit board [12].

(3) Soldering the core chip. Because the CPU and DDR use BGA packages, due to the limited soldering process, soldering should be performed first, and then the video module and Ethernet module should be soldered. After each module is soldered, it is required perform a short circuit break test.

(4) The clock system is the basic reference for the work of digital circuits and is also a key part of the smallest system of the CPU. Using an oscilloscope to measure the key clock to ensure that the crystal oscillator shakes and the waveform is normal.

(5) Flash read and write timing is an important part of the system design. As shown in Table 2, the table lists the key timing parameters in flash work and gives the actual measured values of the design circuit. Typical values are compared to verify the circuit design [13].

Table 2. Flash key timing

Serial number	Parameter	Index(ns)	Measured value(ns)	DifferenceDifference
1	Read Cycle Time	Min 35	40	5
2	Write Cycle Time	Min 25	32	7
3	CE Access Time	Max 25	23	2
4	CE High to Output	Max 30	25	5
5	RE Access Time	Max 20	15	5
6	RE High to Output Hi-Z	Min 100	110	10
7	Data Setup Time	Min 15	20	5
8	Data Hold Time	Min 5	15	10
9	CLE Setup Time	Min 12	14	2
10	CLE Hold Time	Min 5	10	5

The purpose of checking the network connection and network communication test is to test whether the Ethernet communication function of the vision sensor meets the design and application requirements. The test result is shown in Figure 7.

In each data transmission, the client sends a small data query packet to the server. After the server receives the request, it returns the result data with a large amount of data after processing [14]. Through instructions, the process of multiple requests/responses to the network system in the same TCP connection is realized. The test results are shown in Figure 8.

Through various evaluation indicators of the effect of pixel-level image fusion, the average value method and the multiimage fusion method are compared [15]. Calculating the cross entropy, average absolute error, mean square error, signal-to-noise ratio, and peak signal-to-noise ratio between the fused image generated by the two algorithms and the original image, as shown in Table 3.

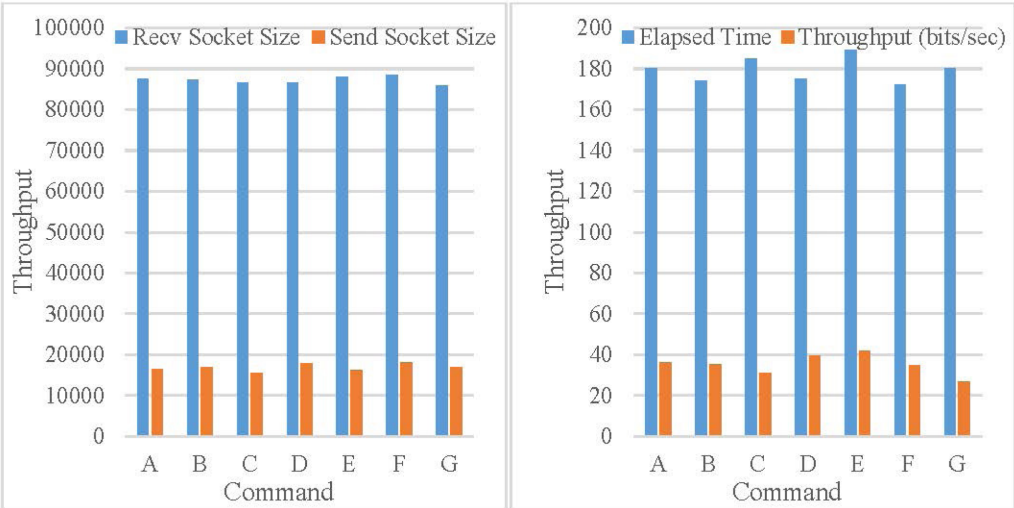

Figure 7. Batch network traffic measurement results

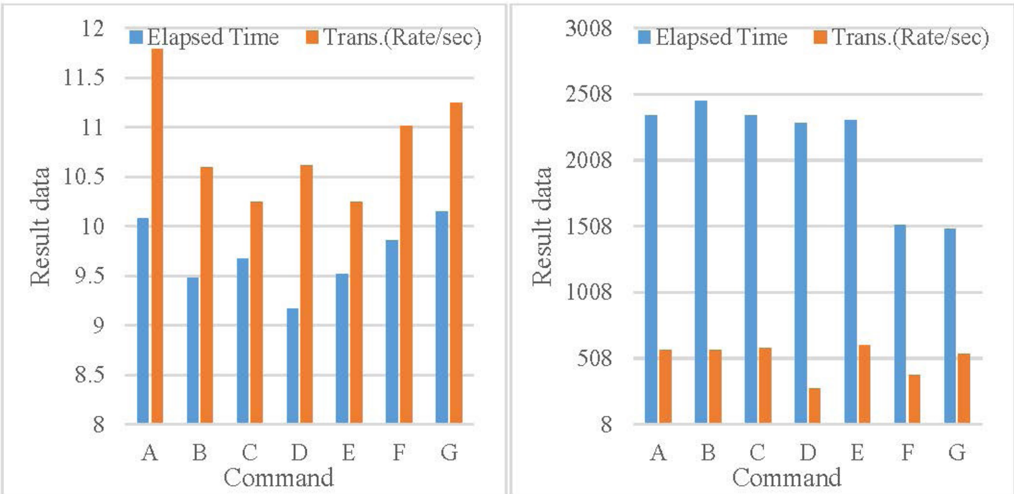

Figure 8. Instruction execution result

Table 3. Comparison of fusion effects

	Averagemethod	Multi-image fusion method
Cross entropy	0.5485	0.4715
Mean absolute error	10.9485	7.4961
Mean square error	285.1864	145.3218
Signal-to-noise ratio	21.8462	24.4861
Peak signal-to-noise ratio	23.1549	26.3184

There are three ways to improve the accuracy of linear light vision sensors: (1) wise camera selection and internal settings; (2) selecting appropriate software algorithms to improve the accuracy of image point coordinate retrieval; (3) Optimization of sensor configuration parameters. After the camera detects, the accuracy of the image point depends on whether the position is a fixed value, and the measurement accuracy of the video sensor depends on the design parameters of the sensor.

The design process of key parameter optimization is as follows: (1) According to the specific design requirements and the current conditions of the sensor, determine the relationship between the parameters to be executed, and determine the constraints of the parameter value range according to the parameter equation. (2) The items corresponding to the optimal structural parameters are defined, and the parameter optimization equations are additionally defined. (3) Create a suitable program, perform optimization simulation, and determine the best structural parameters of the sensor. The simulation results are shown in Table 4.

Table 4. Simulation results

CCD camera parameters	δ / m	f / m	$\lambda(°)$	L / m	$\beta(°)$	$B \times H$ (mm)	S
Camera size 3.6mm×4.8mm Number of pixels 795×596	2	8	12.7	175	55	152×120	56.4
				170	60	135×110	47.5
				165	75	109×100	33.8
				155	78	100×75	30.1
		12	8.52	190	40	144×142	64.8
				185	45	123×114	50.5
				180	55	107×81	34.8
				175	58	91×74	31.2

The ink painting recognition process of the visual sensor based on color features and texture features can be specifically described as:

(1) Read the sample data of pen-and-ink painting images;

(2) Use visual sensors to extract the texture and color features of pen and ink images;

(3) Obtain the category code of pen and ink painting;

(4) Divide the feature vector of the pen-and-ink painting image into training samples and test samples, input the feature vector of the pen-and-ink painting image of the training sample, and use the pen-and-ink painting category of the training sample as the output to train the vision sensor;

(5) For the test samples of pen and ink images, visual sensors are used to identify the color and texture characteristics of pen and ink images.

Figure 9 is a sample of feature data of different types of pen and ink paintings.

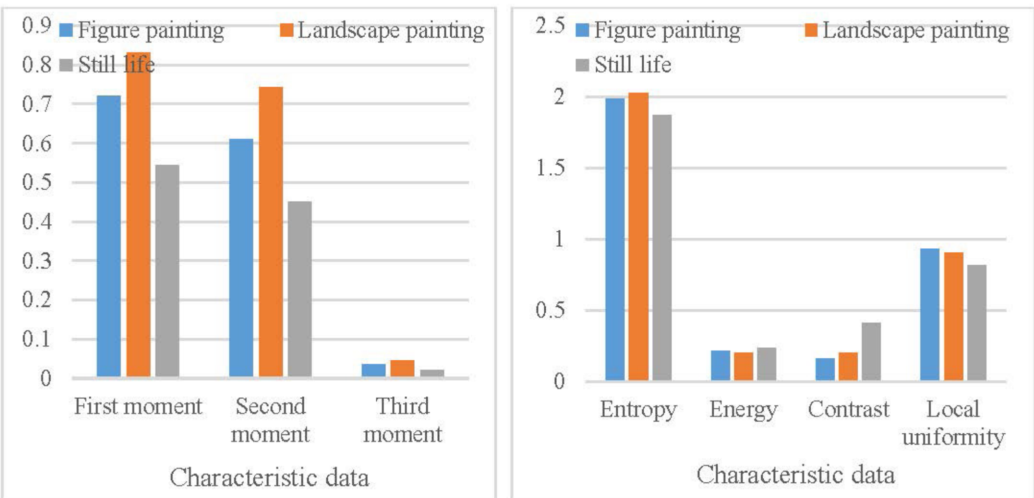

Figure 9. Sample feature data of different types of pen and ink paintings

To verify the effect of the visual sensor, 6 groups of comparative experiments are designed, each group of experiments has 100 pen-and-ink paintings, and the color and texture of the pen-and-ink paintings are recognized by the visual sensor. The experimental results are shown in Figure 10.

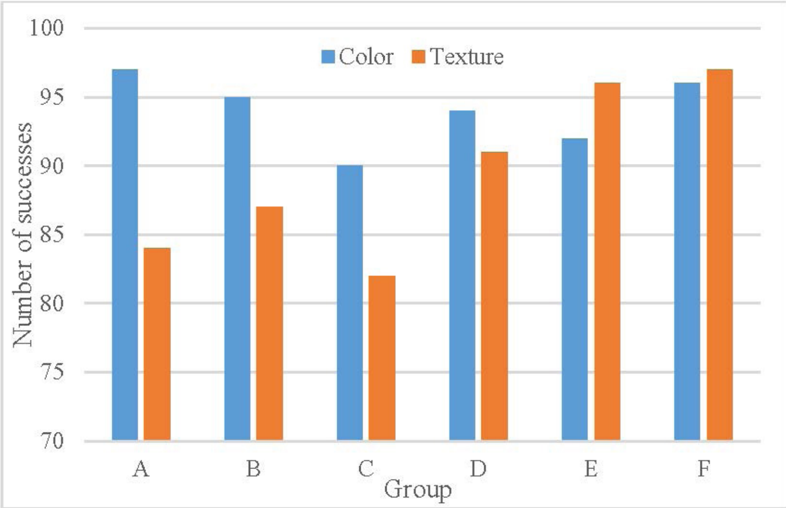

Figure 10. Color and texture success data

4 Discussion

The mathematical model of the visual sensor is an important part of the visual inspection process. According to the choice of model parameters, there are two basic modeling methods:

(1) Making full use of the projection transformation theory, and associate the image coordinate system with the original measurement coordinate system through intermediate parameters that have no physical meaning.

(2) The internal structural parameters of the camera are related to the geometric and visual characteristics of the camera, while the internal structural parameters of the sensor are related to the azimuth parameters relative to the reference system in the image information [16].

Active vision sensors are based on the triangle principle. These shape sensors use geometric structure data from special light sources to provide 3D data about the coordinates of the object's surface. Lightweight, very simple and economical, this is the only equipment that requires a projector and a camera.

5 Conclusion

Vision is the most important means for humans to learn from nature. For many years, people have dreamed of replacing part of manpower in industrial and mechanical practice. This paper introduces a vision sensor to identify the color and texture of the pen and ink painting, obtains the power supply diagram of the vision sensor system circuit, and tests the vision sensor. The current fast matching algorithm is only based on the image library collected under laboratory conditions. There is still a long way to go to the specific application of the algorithm in industrial inspection. Next, we should consider the image directly collected from the inspection site for algorithm verification.

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Biography

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