Design of Multi-spectral Anti-counterfeit Image Acquisition and Detection System

Xingyu Zhou
Beijing Key Laboratory of High-end Printing Equipment Signal and Information Processing
Beijing Institute of Graphic Communication, Beijing, China

Peng Cao
Beijing Key Laboratory of High-end Printing Equipment Signal and Information Processing
Beijing Institute of Graphic Communication, Beijing, China

Xia Zhang
Beijing Key Laboratory of High-end Printing Equipment Signal and Information Processing
Beijing Institute of Graphic Communication, Beijing, China

ABSTRACT
Multi-Spectral Images (MSI) technology has received widespread attention in recent years in the field of printing information anti-counterfeiting because of its significant advantages in information hiding, anti-copying, etc. The development of MSI technology is affected by multiple factors such as light source, camera, hardware, and software systems and algorithms, and is subject to mutual constraints, which puts high demands on the hardware, software, and optical system design. In this paper, we design an MSI acquisition and detection system with a spectral range from 265nm to 1700nm, covering the full spectral range of ultraviolet light, visible light, and near-infrared light, and give the hardware and software system framework of the detection system. In terms of hardware design, the cooperative control of peripherals and multispectral light sources is realized by using an ARM architecture chip as the control unit. For software design, the MSI acquisition software system was developed using Qt Creator with Linux as the operating system. At the same time, the hardware design and software algorithm are optimized to solve the problems of fast switching of multi-spectral light sources and their compensation of light decay. After experimental testing, the system realizes the functions of transient time-division acquisition of MSI information, adaptive adjustment of the light source, and light decay detection, which have the value of popularization and application.

Keywords
multispectral images; printed information anti-counterfeiting; hardware and software systems; time-division multiplexing;

1. INTRODUCTION
In recent years, machine vision technology has been widely used in scientific research and industrial fields by virtue of its advantages of intelligence, automation, and high precision. In addition to visible light imaging technology, people are paying more and more attention to hyperspectral imaging technology and multispectral imaging technology [1-3]. Compared with visible light imaging technology, hyperspectral/multispectral imaging technology has two-dimensional spatial information at the same time, but also one-dimensional spectral information fusion, the formation of the image unique three-dimensional information characteristics, widely used in the field of food quality inspection, plant characteristics detection, pedestrian detection, remote sensing and so on [4-7]. Hyperspectral image acquisition systems in order to obtain spatial spectral data, usually use complex spectral systems and imaging modules for information acquisition, but too complex spectral systems and imaging systems for imaging speed and processing speed will have a greater impact [8-9]. In fact, in the field of multispectral anti-counterfeiting image detection, the number of spectra used is small, and there is no need to obtain a large number of spectral bands, so redundant spectral data need to be eliminated during acquisition. This system realizes the simplification of image spectral data and improves the detection efficiency by discretizing the spectral bands and providing the specific spectra required for detection.

Some existing multispectral image inspection equipment consists of a camera, a multispectral light source, a spectral prism, a carrier stage, and an integrating sphere-type housing [10]. There is a defect in this system, that is, it can only perform image acquisition, can not provide multispectral image-related processing algorithms, and must be connected to a host computer to analyze in order to process the information. To address this problem, this paper designs an embedded system as an image acquisition terminal, which can realize the completion of the whole process from image acquisition to processing to real-time display of the results locally and reduce the dependence on the host computer.

In this paper, a multispectral anti-counterfeiting image detection system is designed for multispectral anti-counterfeiting images, and the hardware design and software algorithm is optimized. The light source is designed to cover the full spectral range of ultraviolet light, visible light, and near-infrared light. The time-division multi-path acquisition of multi-spectrum anti-counterfeiting images is realized through the cooperative control of the light source module and the image acquisition module. The light source control module is embedded with adaptive adjustment and light decay detection algorithm, which can automatically adjust the intensity of the light source according to the actual detection environment and the use of the light source to improve the quality of image acquisition.

2. DESIGN OF MULTISPECTRAL ANTI-COUNTERFEITING IMAGE DETECTION SYSTEM
The design of the multi-spectral anti-counterfeiting image detection system is divided into image detection system hardware design, multi-spectral light source design, and software system design. The detection system and the multi-spectral light source work together through the application program and the communication serial port, and then the multi-spectral image transient time acquisition is realized.

2.1 Image Detection System Hardware Design

In order to realize the acquisition and detection of multispectral anti-counterfeiting images, it is necessary to design an image acquisition and detection system with image acquisition and processing functions and rich peripherals. Currently, there are three mainstream architectures for image detection systems: FPGA architecture, x86 architecture, and ARM architecture, and the architectural comparison is shown in Table 1. The image detection system of FPGA architecture can process a large amount of image data by virtue of its parallel computing advantage [11], but its multi-tasking ability is insufficient and difficult to develop. The image detection system of x86 architecture can be equipped with the Windows operating system, rich in software resources and low development threshold, but it is expensive, and power consumption is high[12]. ARM architecture of the image detection system compared to the x86 architecture in terms of cost and power consumption has a greater advantage, due to its equipped with the embedded operating system, compared with the FPGA architecture of the image detection system in the system control, multitasking synergies have a significant advantage, but its processing power compared to the FPGA architecture and x86 architecture is slightly lower. Since the designed detection system needs to control a large number of peripherals, this paper adopts the ARM architecture chip as the control unit with peripheral circuits for the design of the image detection system, which realizes the image acquisition and the cooperative control of the light source and other peripherals.

Table 1. Comparison of architecture parameters of Inspection equipment

Schema type	Processing method	Multitasking capability	power wastage	costs
FPGA	Parallel computing	Weak	High	High
X86	Serial computing	Strong	High	High
ARM	Parallel computing	Strong	Low	Low

The framework of the hardware system is shown in Figure 1, including the central processing module, storage module, communication module, control module, light source module, image acquisition module, and power module. The central processing module serves as the carrier of the Linux operating system and provides a variety of peripheral interfaces to realize corresponding control. The storage module saves system files, application programs, acquisition data, analysis results, etc. in an EMMC or SD card. The communication module carries out inter-board communication through the serial port, USB, etc. to realize real-time control of peripheral modules such as light source; it communicates with other devices through Ethernet, WiFi, Bluetooth, etc. to realize image data transmission and other functions. The control module uses the touch screen as the main control mode, with physical buttons for simple function operation, and can also use the USB port to access input devices for control. The light source module is divided into two parts: light source driver and multi-spectrum light source, the light source driver is responsible for accepting light source switching commands, light source adaptive adjustment, and light failure detection; the multi-spectrum light source provides a variety of wavebands to enhance detection universality. The image acquisition module consists of an onboard camera accessed through the MIPI interface and a drive-free camera accessed through the USB interface, which increases the flexibility of image acquisition. The power supply module provides multiple voltage outputs to ensure the normal operation of each module, and the design of the power-on timing control circuit and leakage detection circuit enhances the stability of the system.

2.2 Multi-spectral light source design

The diversity of spectral channels used in multispectral anti-counterfeiting images leads to the complexity of the detection equipment, some anti-counterfeiting packaging or anti-counterfeiting images contain a variety of spectral information, only a single spectral light source can not be achieved by the full extraction of anti-counterfeiting features, despite the existence of light source replacement parts, but the disassembly and re-installation process will take a certain amount of time, which affects the detection speed and quality of the detection, so a composite spectral light source is designed, integrated with a variety of light sources commonly used for detection, and different light sources are driven independently through the light source driver board, which reduced time costs due to different testing conditions. The testing environment may vary greatly depending on the item to be tested or the testing location, and the testing quality may be disturbed by external factors such as ambient light. , therefore, in the design of the light source module to join the adaptive mechanism, relying on the adaptive adjustment of the light source driver to reduce the overhead brought about by the application level processing, and improve the speed and quality of detection.

Table 2. Types of light sources

LED type	Illumination Angle	Application field
Visible light	Top, side, bottom	General anti-counterfeiting image detection
UVA	Top	Currency, document detection, special fluorescent image detection
UVC	Top	Currency, document detection, special fluorescent image detection
NIR	Top, side, bottom	Defect detection, food quality detection, special anti-counterfeiting packaging detection

The light source driver board reserved 16 groups of light source interface, the light source board can be individually designed and connected through the reserved interface, to achieve the effect of plug and play. The power supply interface of each light source is an independent interface, which can operate multiple light sources at the same time to achieve the effect of compound spectral detection.

From the angle of illumination of the light source, the top light source can clearly show the surface characteristics and details of the object, but when detecting the surface light reflection coefficient is too high, it is easy to leads to camera overexposure; the side light source can to a certain extent to avoid this problem, and at the same time for to be detected for the object's texture characteristics have a strong highlighting effect; the bottom light source for the detection of semi-transparent objects, you can highlight the object's contour information and the surface of the bumpy changes, but for the less transparent or high light reflection rate of the object the effect is poor. However, it is less effective for objects with

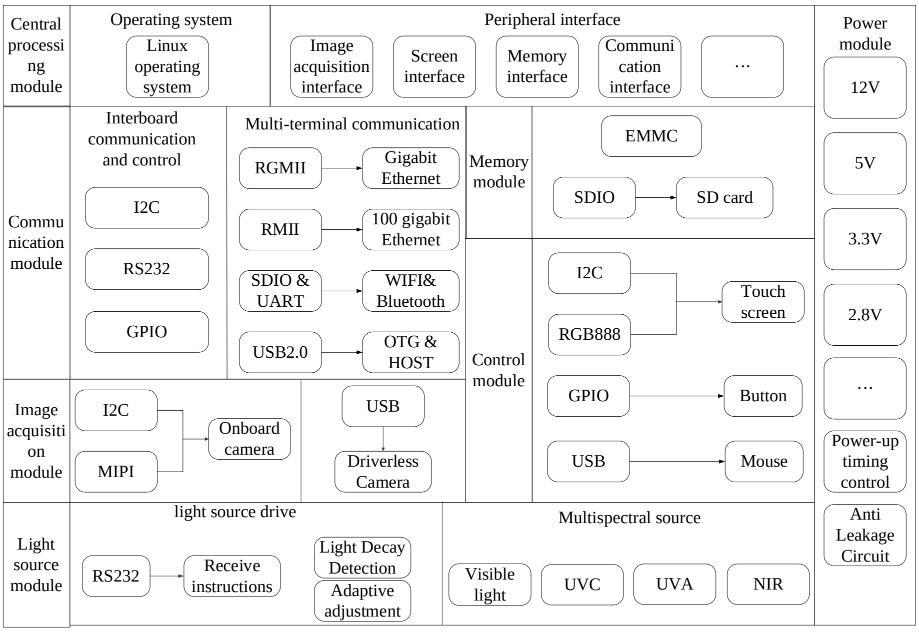


Figure 1: Hardware system framework

low transparency or high light reflectivity. Therefore, in the light source design of this paper, a variety of wavelengths are used in the type of light source, and the space is designed with the top light source, the bottom light source, and the side light source of the full enclosure, which can satisfy some special detection conditions. The types of light sources used are shown in Table 2.

2.3 Multi-spectral image acquisition software system design

The hardware system designs the image acquisition and processing system and multispectral light source and integrates the two into a complete multispectral image acquisition system, which needs to build a complete software system to coordinate the tasks of each module and realize the functions of multispectral image acquisition, adaptive adjustment of the light source, and detection of light decay. The architecture of the software system is shown in Figure 2.

The detection system uses the Linux system as the control system, compiles the peripherals into the Linux kernel in the form of device drivers, and the application realizes the control of the peripherals by calling the system API. Qt Creator is used to design the visualization interface application, and real-time interaction is realized by matching with input devices such as a touch screen or mouse, which can choose to display the image information on the screen or push the image information to the cell phone through RTSP protocol after compression and encoding for display. The processing layer adopts different processing strategies according to the size of the image data, the processing of small data or simple algorithms is completed directly in the detection system locally, while larger data or more complex processing algorithms can be uploaded to the server, through the high-performance servers to complete more time-consuming tasks to improve the detection efficiency and improve the user experience.

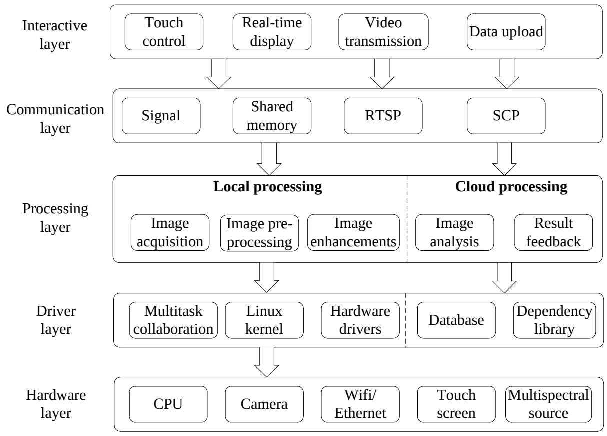


Figure 2: Software system architecture

3. RELATED FUNCTIONS IMPLEMENTED

The system has built-in functions of light source adaptive adjustment, light decay detection, and multi-spectral image transient acquisition, which can realize image acquisition under various environmental conditions.

3.1 Light Source Adaptive Adjustment

In the image acquisition process, different detection environments provide different light conditions, and in most environments, it is necessary to adjust the exposure time of the camera to ensure the imaging quality. In darker environments, the exposure time needs to be increased to obtain enough light, but while increasing the exposure time, a series of problems will arise, such as thermal noise from long exposure, automatic noise reduction leading to loss of image details, streaky artifacts due to camera shake, dynamic blurring and so on. All these problems will have a certain impact on the imaging quality, so the multispectral light source module that assists in image acquisition needs to embed an adaptive adjustment mechanism to change the intensity of the light source according to the detection environment to avoid the problems caused by the long exposure time of the camera.

The light intensity distribution of a single light source in the light source plate can be approximated as a Lambertian distribution, and the relationship between its luminous intensity and luminous angle is shown in Eq. 1:

$$I(\theta) = I_0 cos^m \theta \quad 1$$

In Eq. 1, θ is the light-emitting angle; I_0 is the light intensity of the point light source at $\theta = 0^\circ$; the value of parameter m depends on the light intensity of one-half of the light-emitting angle of I_0 [13], and the relationship is specifically expressed in Eq. 2:

$$m = \frac{-ln2}{\ln (cos\theta_{\frac{1}{2}})} \quad 2$$

Any point on the light source plate as the origin to establish a spatial coordinate system, assuming that the coordinates of the point light source for the (X, Y, 0), which is to be detected on the plane of the (x, y, z) at the illuminance is shown in Eq. 3:

$$E(x, y, z) = \frac{z^{m+1} I_0}{((X-x)^2 + (Y-y)^2 + z^2)^{\frac{m+3}{2}}} \quad 3$$

Since the light sources on the light source plate are arranged in a rectangular array, the illuminance at any point (x, y, z) on the plane to be detected is shown in Eq. 4:

$$E(x, y, z) = \sum_{i=1}^{n} \frac{z^{m+1} I_0}{((X_i-x)^2 + (Y_i-y)^2 + z^2)^{\frac{m+3}{2}}} \quad 4$$

$X_i$and Y_i in Eq. 4 are the coordinates of the ith light source in the light source array. Let the illumination received by the surface of the item to be inspected be uniform within a certain range, then the actual illumination at any point on the plane to be inspected is shown in Eq. 5:

$$E_{real}(x, y, z) = E(x, y, z) + E_{env}(x, y, z) \quad 5$$

Where E_{env} is the illuminance of ambient light on the surface of the item to be detected. Under the fixed position and environmental conditions, the light irradiance received by the camera is directly proportional to E. When the light irradiance received by the camera is too high, it leads to overexposure, and vice versa, it leads to underexposure, which ultimately results in the distortion of the captured image information, and therefore it is necessary to collect the current environmental information before turning on the detection and adjust the parameters of the light source.

The STM32F103C8T6 chip has two ADCs, each with 18 channels, 16 external and two internal, and channel 4 of the ADC1 is used as the sampling channel in the light feedback module. The ambient light intensity parameters are collected and compared with the preset parameters by the light feedback module.

ADC for acquisition is to convert analog signals to digital signals, the ADC of the STM32 is a 12-bit successive approximation type analog-to-digital converter, so after the actual analog signal acquisition the conversion formula is shown in Eq. 6:

$$V_{real} = V_{max} * \left(\frac{temp}{2^\alpha}\right) \quad 6$$

Where V_{max} is the maximum voltage that can be captured by the ADC, $temp$ is the converted value of the ADC module, α is the number of ADC resolution bits, and V_{real} is the actual sampling value. In order to obtain a high degree of accuracy, the conversion time of the ADC module can be set, and the conversion time equation is shown in Eq. 7:

$$T_{sum} = n * T_{abc} + 12.5 * T_{adc} \quad 7$$

Where n is the number of sampling cycles that can be set and T_{abc} is the sampling period. To obtain the highest accuracy, the actual design sets n to 239.5, which means that the conversion time is 252 sampling cycles or about 21us. In the actual detection is susceptible to sudden changes in the situation therefore the collected data need to be removed from the error, the data correction formula is shown in Eq. 8:

$$V_{sum} = \sum_{n=1}^{N} V_{real}(n) - MAX(\beta * N) - MIN(\beta * N) \quad 8$$

Where N is the total amount collected, β is the error ratio, and V_{sum} is the sum of the sampled values after removing the error. The actual value after removing the error is then averaged to get the final result with the following expression:

$$V_{avg} = \frac{V_{sum}}{N * (1 - 2\beta)} \quad 9$$

Through Eq. 4, it can be seen that the light intensity at a certain point with a fixed array of light sources can be expressed by the Eq. 10:

$$E(x, y, z) = I_0 * sum(x, y, z) \quad 10$$

Where I_0 is the light intensity of the current light source at $\theta = 0^\circ$ and $sum()$ is the summation formula in Eq. 4. The larger I_0 is, the larger the light intensity is, and V_{led} is shown in Eq. 11:

$$V_{led} = V_{max} * \left(\frac{f\big(E(x, y, z)\big)}{2^\alpha}\right) \quad 11$$

Where $f()$ is the conversion function of the light intensity to the ADC sampling value. Let the camera's normal acquisition of images, the required light intensity converted by the ADC voltage is V_{norm} , the current ambient light intensity converted voltage is V_{env} , then the adaptive adjustment mode is shown in Eq. 12:

$$V_{led} = V_{norm} - V_{env} \quad 12$$

$$I_t = \frac{f^{-1}\left(\frac{V_{led} * 2^\alpha}{V_{max}}\right)}{sum(x, y, z)} \quad 13$$

The desired luminance I_t of the light source after adaptive adjustment is obtained by Eq. 13.

3.2 Adaptive light decay adjustment

LED light source converts electrical energy into light energy, this process produces a large number of losses, and the light-emitting process produces a certain amount of heat, according to the LED production materials and process of LED production, the impact of this heat on the luminous efficiency of the different, but will lead to a certain degree of light failure, with the increase in working time, the light failure will be more serious, resulting in deterioration of the detection effect, and therefore the need to compensate for the adjustment to ensure that the detection of the quality of [14].

The volt-ampere characteristics of LEDs cause them to require a higher current to achieve the same operating voltage as the temperature increases. The increase in current leads to increased heating of the LED, into a vicious circle. Therefore, a constant current source is used to power the light source to extend its service life.

Over Eq.12 can be seen, according to the environment after adaptive adjustment led light intensity will reach a standard value and allow a certain range of error, but after the occurrence of light decay the actual light intensity is not up to the level of the need to be namely:

$$V_{real} < V_{led} - V_{err} \quad 14$$

Where V_{real} is the voltage into which the current light intensity is converted, V_{led} is the standard voltage, and V_{err} is the error. Need to compensate for the adjustment to meet the demand, due to different lengths of use of led or different models of led light source luminous efficiency is different, the adjustment needs to be based on the actual gap between the gain parameters automatically adjusted to avoid the adjustment of too fast resulting in too high a brightness, the compensation formula is shown in Eq. 15:

$$V_{real}(T) = V_{real}(T-1) \mp f(V_{led}, V_{T-1}) * V_{inc} \quad 15$$

where T is the number of detection rounds, $f()$ is the gain multiplier calculation function, and V_{inc} is the default compensation value. If the standard still cannot be reached when the power is boosted to the maximum, it can be used with the upper computer program to remind the user.

3.3 Transient Time-Division Acquisition and Processing of Multispectral Images

Multi-spectral image anti-counterfeiting use of the uniqueness of the spectrum will be hidden information in different spectra, these information may not interfere with each other, and each spectral channel information can be recognized; may be the information in each channel contains only a part of the complete hidden information, the need for more than one spectral integration of information to generate a complete hidden information; may be a channel of information contains a large amount of noise, the need to match the other spectral information to achieve the noise rejection, and ultimately to generate recognizable hidden information of the original.

In the acquisition process, the object to be detected or the camera may be disturbed by external factors to produce spatial position shift, the information located in different spectral channels will also be shifted, resulting in failure of information integration, unable to recognize or recognize of the correct rate is low. Therefore, the acquisition system needs to be specialized processing, multi-spectral image acquisition relative to visible light image acquisition from the photoreceptor chip end to the light source end has greater differences, and the spectral response range of the photoreceptor chip needs to be increased to the near-infrared, the light source needs to be quickly switched in order to achieve the effect of the spatial position of the image to be captured is nearly unchanged.

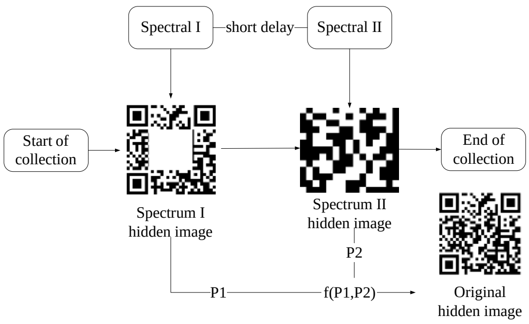


Figure 3: Multi-spectral image composite recognition

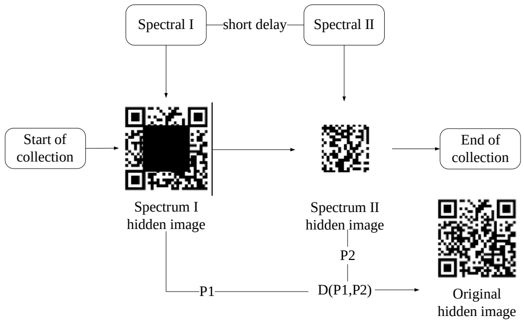


Figure 4: Differential recognition of multispectral images

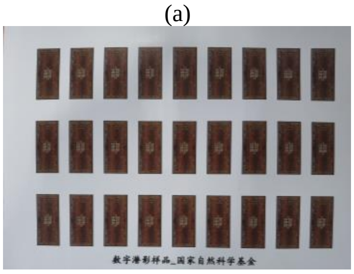
The multispectral image recognition process is shown in Figure 3 and Figure 4, where the acquisition mode is selected according to the spectral channel in which the hidden information is located, the detection system acquires the images under the selected spectral channel, and the image acquisition achieves the ideal effect by presetting the image acquisition parameters and the light source parameters, which reduces the time overhead generated by the adaptive adjustment. Set the collected image information under the first spectrum as P_1, the collected image information under the second spectrum as P_2, the processing mode in Figure 3 is image fusion, and the collected image P_1 under the conditions of the first spectrum only contains a part of the original hidden image, which can not be read normally, through the collection of the other spectral images under the P_2, and the two are fused to generate a recognizable image. The processing method in Figure 4 is image differencing, the image P1 acquired under spectral one conditions contains a large amount of noise in addition to the complete original hidden image, and the image acquired under spectral two is a noisy template, and the original image without noise is obtained by performing the differencing operation on the two images.

4. EXPERIMENTAL RESULTS AND ANALYSIS

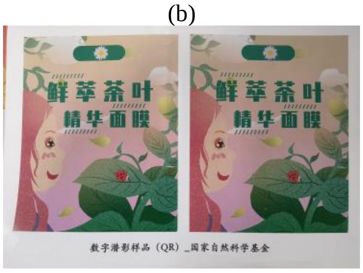
4.1 Monospectral Image Acquisition

The image of the fluorescent anti-counterfeiting carrier image captured under visible light is shown in Figure. 5(a), and the surface of the carrier is blank and does not contain valid information under visible light. The multi-spectral composite images printed under the long-wave ultraviolet spectrum and short-wave ultraviolet spectroscopy are collected through the designed detection equipment, and the hidden information under different spectra, such as QR code, dot-matrix code, and stamp image, can be clearly collected, and the actual collection diagram is shown in Figure. 6. When the system is collecting, the UVA and UVC light sources are turned on separately, and the hidden information collected under each light source does not interfere with each other and is completely independent. The QR code and dot-matrix code captured by the system can be read directly by cell phones and partly by customized applications. Since the two fluorescent images are placed in the same position and occupy a smaller area, in practice, merchants can place both fluorescent images into the package, including the QR code or logo image under visible light, so that multiple anti-counterfeiting can be realized in a smaller area. The use of this system for inspection reduces the time and equipment costs associated with changing light sources or changing inspection equipment.

(a)



(b)



(c)

(d)

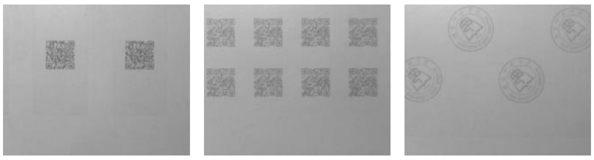
Figure 4：Original multispectral image

The NIR anti-counterfeiting carrier images acquired under visible light are shown in Figure. 5(b), (c), and (d) with visible light images on the carrier. Since the camera needs to meet the multi-spectral band response and thus does not have a built-in filter, the hidden NIR spectral image information will be interfered with by the visible light image information when the NIR spectral image is acquired, so it is necessary to cooperate with the filter or place the object to be detected in a dark room to shield the interference of other light sources during the acquisition. Through the fast and high-quality acquisition of near-infrared images, clear logos or two-dimensional codes can be obtained, and the near-infrared spectral images acquired by the system are shown in Figure 7.

The unique nature of fluorescent anti-counterfeiting images and infrared anti-counterfeiting images makes them difficult to copy or forge. Merchants can implant the value-added services and authenticity-checking features of their products in the form of QR codes into the packaging or labels to realize the anti-counterfeiting effect, and the multispectral detection system designed in this paper can quickly and accurately detect and identify these images to help consumers and merchants confirm the authenticity of their products. Brand owners can also protect their brand image and reputation by using the multispectral detection system. If counterfeit goods are detected, timely action can be taken to prevent further infringement.

UVA QR code | UVC QR code | UV dot matrix code | UV Stamps

Figure 5：Ultraviolet fluorescence image



(a) (b) (c)

Figure 6：Near-infrared spectral image

4.2 Transient time-division acquisition of multispectral images

Multi-spectral images in different spectral channels to hide different information, merchants can be divided into multiple channels to hide the anti-counterfeiting information, the detection system designed in this paper through the coordination of the image acquisition module and multi-spectral light source module to achieve multi-spectral image transient time-division acquisition. In order to ensure detection quality and efficiency, this paper conducted experiments on the acquisition mode to find out the best image acquisition mode. The acquired images are shown in Table 3. The images in Table 3 are carrier image, UVA image, and UVC image from top to bottom.

As can be seen from Table 3, the overall detection effect gap is smaller when the light source switching interval is more than 1s, and when the light source switching interval is 0.5s, the quality of both the original and the long-wave UV image acquisition is poorer. Considering the overall detection time, it was decided to optimize the acquisition process with a light source switching interval of 0.5s. The optimization results are shown in Table 4.

Table 3. Comparison chart of acquisition effect

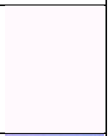
	Light source switching time			
Image type	**2s**	**1.5s**	**1s**	**0.5s**
Carrier Image				
UVA				
UVC				

Table 4. Optimized acquisition results

Optimization method	**Carrier Image**	**UVA**	**UVC**
Reduced exposure time			
1/2 aperture			
1/4 aperture			

The main problem of the acquisition results in Table 3 when the light source interval is 0.5s is that the image is overexposed, which is caused by the long time required for the camera to adapt itself and the short switching time of the light source, and therefore optimized from the exposure time and aperture size. After experimental testing, the optimal results of reducing the exposure time are shown in the first row of Table 4, compared with Table 3, the original image and the long-wave UV image have been optimized to a certain extent but the quality of the short-wave UV image has decreased significantly. Reducing the camera aperture to 1/2 and 1/4 of full respectively, it was found that the best results were obtained when the aperture was 1/4 of full, and the image quality of the original image, long-wave UV, and short-wave UV spectra were excellent.

This system avoids the hidden information mismatch generated by the offset of the item to be detected in the spatial position through the transient time-division acquisition of multi-spectral images. Merchants can port the application to the detection equipment according to their needs to realize the fusion of multiple spectral image information, and thus achieve the purpose of high-quality anti-counterfeiting.

4.3 Adaptive adjustment of light source and light decay detection

4.3.1 Light Source Adaptive Adjustment

According to the actual use, three conditions of strong ambient light, weak ambient light, and no ambient light are simulated for testing, and the actual test results are shown in Table 5. In the three environments, the quality of the images collected by the detection system can meet the requirements of reprocessing, which verifies the stability of the system.

When the ambient light is strong, the light source driver board provides lower compensation or no compensation, and when the ambient light is weak, the light intensity value captured by the light source driver board is small, which is not up to the standard of normal image acquisition, so it is adjusted according to the current ambient light intensity and the adaptive adjustment model, and the result of the adjustment is shown as Fig. e in Fig. 10, and when there is no ambient light, the compensation power is turned on to the maximum, and the image captured after adjustment is shown as Fig. f in Fig. 10. f in Fig. 10. The quality of the regulated image acquisition is good and can meet the demand of subsequent processing.

Table 5. Effect of Adaptive Light Source Adjustment

Image type	**Higher ambient light**	**Low ambient light**	**No ambient light**
Original figure			
Adaptive adjustme nt			

4.3.2 LED light source light decay adaptive adjustment

Using a normal LED light source, the light decay scenario was simulated by increasing the light intensity criterion to the upper sampling limit. The actual adjustment process is shown in Table 6. In the actual sampling, the lower sampling value indicates the higher light intensity. Table 6 shows that in the process of actual adjustment of the LED light source, the rate of adjustment is related to the current LED light intensity, the closer to the target light intensity, the slower the rate of adjustment, and when the upper limit of the output power is reached and the standard light intensity is not reached, a warning is sent to the host computer, prompting the user to indicate that the light source has reached the end of its service life.

Table 6. Adaptive adjustment process of light attenuation

Adjustment rounds	**Sampling value > 3.25**	**3.25 > Sampled value > 3.15**	**3.15> Sampled value**
1	3.2943	3.2186	3.1485
2	3.2919	3.1936	3.1453
3	3.2677	3.1872	3.1453
4	3.2291	3.1654	3.1445

5. CONCLUSION

A multispectral anti-counterfeiting image detection system was built by designing an image detection system and a multispectral light source and integrating the two. Using this system for single-spectrum image acquisition and multi-spectrum image transient time-division acquisition, the hidden information under different spectra can be obtained. The system can also adaptively adjust the light source and detect the light decay of the light source according to the light conditions of the detection environment to ensure the quality of image acquisition and can realize the hidden image detection under multiple spectral conditions without changing the light source. It provides an efficient and reliable solution for printing anti-counterfeiting image detection and promotes the application of multi-spectrum anti-counterfeiting images. However, the detection field of view of the current design of the detection system is relatively fixed, can not change the detection range, multi-spectrum light source adaptive adjustment is mainly for visible light, for other spectral light intensity collection effect is poor, the future will be iterative upgrading of the detection system hardware and software architecture, hardware level to upgrade the existing platform, increase the transmission structure to realize the detection of the field of view can be varied, expand the adaptive adjustment of the light source module, to strengthen the Universal applicability, optimize the acquisition quality and processing speed. At the software level, the value-added function of multi-spectral anti-counterfeiting images will be added to provide more convenient follow-up services.

6. ACKNOWLEDGMENTS

This paper is supported by the Key Lab of Intelligent and Green Flexographic Printing (ZBKT202206) and Research Project of Beijing institute of Graphic Communication (21090123009).

7. REFERENCES

[1] Lu R, Chen B, Cheng Z, et al. RAFnet: Recurrent attention fusion network of hyperspectral and multispectral images. Signal Processing, 2020, 177: 107737.

[2] Pieczywek P M, Cybulska J, Szymańska-Chargot M, et al. Early detection of fungal infection of stored apple fruit with optical sensors–Comparison of biospeckle, hyperspectral imaging and chlorophyll fluorescence. Food Control, 2018, 85: 327-338.

[3] Aasen H, Bolten A. Multi-temporal high-resolution imaging spectroscopy with hyperspectral 2D imagers–From theory to application. Remote sensing of environment, 2018, 205: 374-389.

[4] Saha D, Manickavasagan A. Machine learning techniques for analysis of hyperspectral images to determine quality of food products: A review. Current Research in Food Science, 2021, 4: 28-44.

[5] Ye H, Huang W, Huang S, et al. Identification of banana fusarium wilt using supervised classification algorithms with UAV-based multi-spectral imagery. International Journal of Agricultural and Biological Engineering, 2020, 13(3): 136-142.

[6] Park K, Kim S, Sohn K. Unified multi-spectral pedestrian detection based on probabilistic fusion networks. Pattern Recognition, 2018, 80: 143-155.

[7] Thakur S, Mondal I, Ghosh P B, et al. A review of the application of multispectral remote sensing in the study of mangrove ecosystems with special emphasis on image processing techniques. Spatial information research, 2020, 28: 39-51.

[8] Shen F, Deng H, Yu L, et al. Open-source mobile multispectral imaging system and its applications in biological sample sensing. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 2022, 280: 121504.

[9] Lodhi V, Chakravarty D, Mitra P. Hyperspectral imaging system: Development aspects and recent trends. Sensing and Imaging, 2019, 20: 1-24.

[10] M. J. Khan, H. S. Khan, A. Yousaf, K. Khurshid and A. Abbas, "Modern Trends in Hyperspectral Image Analysis: A Review," in IEEE Access, vol. 6, pp. 14118-14129, 2018, doi: 10.1109/ACCESS.2018.2812999.

[11] Seng K P, Lee P J, Ang L M. Embedded intelligence on FPGA: Survey, applications and challenges. Electronics, 2021, 10(8): 895.

[12] Zefei Xu. Hardware design of smart camera based on Zynq. Nanjing University of Posts and Telecommunications, 2019.

[13] Wang X. LED ring array light source design and uniform illumination properties analysis. Optik, 2017, 140: 273-281.

[14] Zeying Cui, Qingbo Gu. Study on the law of light decay of LED Light source. Semiconductor Technology,2012,37(04):312-315.