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The Light and Image Synchronous Method Based on Adaptive Color Segmentation Algorithm

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Abstract. With the development of Internet of Things technology and the people's pursuit of high-quality life, the development of smart homes is becoming more and more diversified, paying more attention to reducing costs, increasing benefits and user experience. For the scene where lights and images change synchronously in smart homes, the current technology used in related products is a solution for external hardware processing equipment, which has problems such as high hardware cost, complex configuration, only supporting external HDMI sources, etc.. Combined with the above situation, this paper proposes a smart home lighting linkage system that is suitable for market demand, easy to promote, apply and implement. Through ZigBee, Bluetooth networking technology, color segmentation technology, signal processing technology, etc., this solution designs and implements an adaptive lighting linkage smart home system based on the color change of the TV screen. The scheme has been proved to have the characteristics of low cost, good experience and stable effect in practical application, and achieved the expected research goals.

Keywords. Lighting Changes with Movies Scenario, Image Processing, Color Space, Smart Home, Lighting Linkage System

1. Introduction

The initial development of smart home is mainly based on remote control lighting, home appliances and electric curtains. With the development of the industry, the functions of intelligent control are becoming more and more abundant. Like the linkage scene of control, smart home can cover almost all traditional weak current industries, and the market development prospects are promising. For the

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scene in which the lighting and the image change synchronously in the smart home, this life scene is mainly based on the hardware solution. In literature [1], color extraction and synchronized display are implemented by external hardware boxes. The technology adopted by the existing products has problems such as high cost, complicated operation and only applicable to HDMI external input sources, which seriously hinders the promotion, application and development of the product. A music lighting algorithm based on spectrum analysis is proposed in the literature [2]. It is easy to use, but it needs to network lights separately, which is relatively complicated. While in literature [3], a simple equipment and a method for lights to follow music are proposed, but the lighting effect is not ideal. This topic aims to solve the technical shortcomings of existing products, and propose a smart home lighting linkage system that is suitable for market demand, easy to promote, apply and implement. Based on the image processing algorithms, Internet of things, ZigBee, Bluetooth Mesh and other technologies, this paper designs and implements a lighting linkage smart home system based on the color change of TV images.

2. The Design of The System

This paper proposes a lighting linkage system scheme based on the color of the TV screen. The system monitors the subtle changes of the TV screen in real time, and drives the LED smart lights around the TV according to the screen content, so that it presents brilliant and colorful colors. At this time, the TV screen extends beyond the LCD (TV) screen, and the changes of light and shadow break through the limitations of the screen, forming a wider range of visual appreciation, making it echo the TV screen, creating a cinema-like immersive visual enjoyment.

The lamp strip devices form a controllable network through ZigBee technology and Bluetooth Mesh technology. The TV calculates the color of the light strip in real time according to the image color, and sends it to each light strip through the network for control and adjustment, so as to achieve the effect of light linkage. The software interaction process of the whole system is shown in Figure 1. The system consists of two modules, a software application on the TV and network communication. The software applications on the TV are developed in the Kotlin language, known as Swift in the Android world. It collects real-time TV broadcast screen data and extracts valid data except for the black border area. The valid data is divided into color blocks by image algorithm and the main color of each color block is extracted, which the main color block is sent to the light strip device using the local network environment to realize the real-time linkage of the light and color of the TV screen.

The network communication module of the device is mainly constructed through ZigBee technology and Bluetooth Mesh technology. The advantages of this scheme are as follows: 1) low cost, 2) high flexibility, 3) easy to expand. If a new device is added, it only needs to be configured on the network.

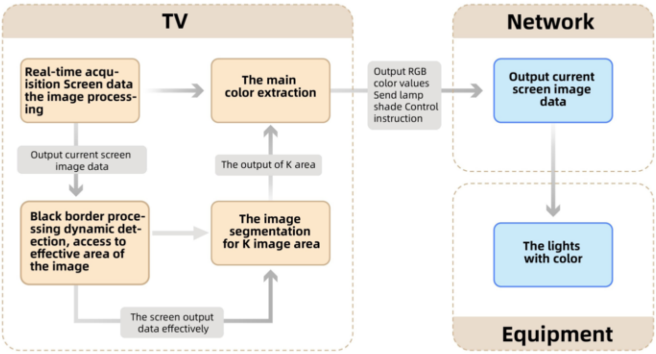


Figure 1. Flow Chart of System Software Interaction

3. Research on the Scheme of Adaptive Change of Light with Image

3.1. Overall Scheme

The overall scheme consists of six modules: real-time TV image acquisition, image compression, video black box detection, image segmentation, main color value extraction and light strip control protocol encapsulation and transmission. The specific workflow is shown in Figure 2:

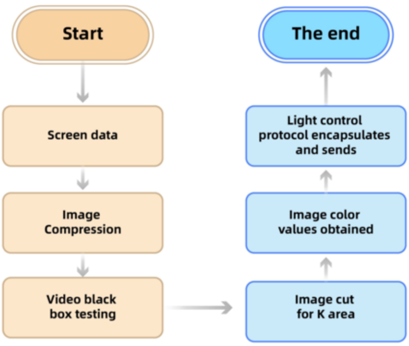


Figure 2. Software Flow Design Diagram

3.2. Design and Implementation of TV Real-Time Image Acquisition and Compression Module

The module is mainly responsible for acquiring TV screen data in real time. Before data collection, it is necessary to initialize the frame rate and screen resolution of the collected screen data, and set the parameters of the screen collection area and the type of collected data. The screen image data acquisition module including the osd layer (graphics layer of the smart TV system for common applications, such as boot animation) and video layer (video layer, TV layer). According to the real-time video playback progress, the image is selected and sent to the subsequent image compression and processing module for calculation.

The module compresses the data obtained by the TV real-time image acquisition module. The color value algorithm is used to extract the image, the larger the image data, the longer the image processing time. In this scheme, images are compressed by K-fold smooth Bresenham scaling algorithm. On the premise of not affecting the extraction of the main color value, it simplifies and reduces the subsequent image processing time to the greatest extent. The smooth Bresenham scaling algorithm is an adaptation of the linear Bresenham algorithm [4], which is used to scale images with quality close to linear interpolation, with optimal scaling factor intervals between 50% and 200%.

3.3. Design and Implementation of Image Black Box Detection Algorithm Module

The commonly used image black-box detection algorithm is based on luminance information. Another black-edge video detection algorithm based on convolutional neural network [5,6], which has high accuracy, but requires more system resources and takes longer inference time on the CPU.

In this paper, a dynamic image black edge detection algorithm based on parameter update is designed and proposed. The algorithm is mainly used to deal with the upper and lower black borders of video images, we remove the black frame, keep the valid data area, and reduce the influence of the black frame on the extraction of main color values. The design idea of black edge detection is to set the maximum black edge threshold (e.g.,1/4 of the image height). Within the threshold, the image is cut into M W*K rectangular images (W is the width of the image, K is the height of the overlay), it is judged from top to bottom whether the rectangular area is black. If it is black, move on to the next one. This detection will eventually maintain a dynamic balance of advancing and retreating near the black frame of the video, so as to achieve the purpose of dynamically updating the parameter information of the black frame. The processing flow of this part is shown in Figure 3:

3.4. Design and Implementation of Image Adaptive Color Segmentation Module

Image color segmentation algorithms [7, 8] are mainly used to extract different color regions in an image, and then perform subsequent color extraction. In this paper, by comparing the effect and performance of three mainstream segmentation algorithms, we summarize the advantages and disadvantages of each algorithm, and propose an image adaptive color segmentation algorithm, which can achieve better segmentation results and take into account the performance. The three algorithms are the region growing-based color segmentation algorithm, the threshold-based color segmentation algorithm and the clustering-based color segmentation algorithm, respectively.

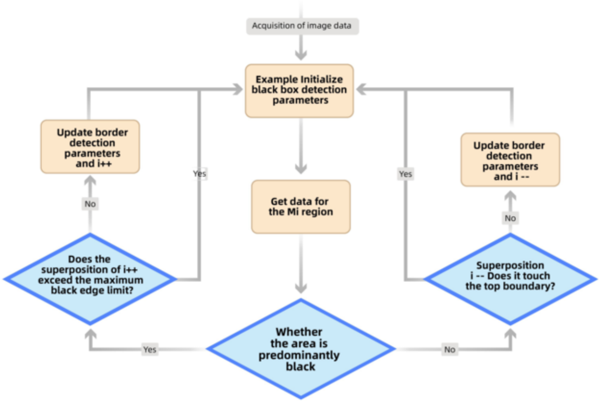


Figure 3. Flowchart of Image Black Box Detection Algorithm

3.4.1. Region Growing Based on Color Segmentation Algorithm

The region-growing-based color segmentation algorithm [9, 10] starts from a pixel or a small region, and judges whether adjacent pixels belong to the same region according to preset rules, thereby gradually growing into regions with the same attributes. The growth of the algorithm is terminated when no pixels meet the specified rules. In this way, this algorithm only considers whether the current pixel belongs to the region, without considering the fusion information of the whole image. The general steps are as follows:
1. Select the appropriate rules and area seeds. The rules can be features such as grayscale, color, texture, gradient, etc. The selected seeds can be a single pixel or a small area containing multiple pixels;
2. Determine the calculation and comparison method of different pixel features in the neighborhood (4-neighborhood or 8-neighborhood);
3. Determine the conditions under which growth stops. The advantages and disadvantages of the algorithm are obvious. On the one hand, the idea of this algorithm is relatively simple, and it can segment the closed area and it will have a good segmentation effect in a complex environment. On the other hand, it is sensitive to noise and prone to holes, so it needs to select seed pixels or regions and fusion rules in advance. Also, too many parameters settings result in high time and space complexity.

3.4.2. Threshold-Based Color Segmentation Algorithm

Another commonly used segmentation algorithm is the threshold-based color segmentation algorithm [11, 12], as shown in Figure 4. According to a large amount of video data, the aspect ratio coordinates of the general color segmentation area are summarized, and the entire picture is artificially divided into ten areas of different sizes. The algorithm is too simple , works best on the reference video set and has the fastest processing speed. However, for the non-reference video set, when the color regions of the pictures is irregular, the segmentation effect is poor. The segmentation area cannot be updated dynamically, and the user experience is poor.

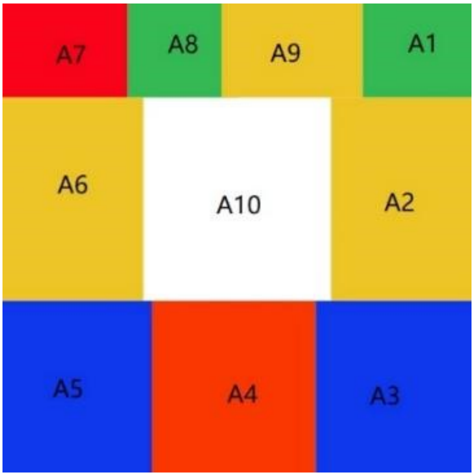


Figure 4. Schematic Diagram of Threshold-Based Region Cutting

3.4.3. Clustering-Based Color Segmentation Algorithm

The color segmentation algorithm based on clustering [13, 14] mainly divides the sample points of the vector space into K subspaces according to a certain distance measure, and the result of the clustering feature is the membership degree of the data to the cluster center. It will make the points in the subspace as close together as possible and the adjacent subspaces as far apart as possible.

In this algorithm, we use the RGB three channels of the color images as the X, Y and Z axes to establish a spatial Cartesian coordinate system, and then establish a one-to-one correspondence between each pixel on the image and the spatial Cartesian coordinate system. K points are randomly selected from the spatial Cartesian coordinate system as the centers of the K subspaces. The distances from all pixels to K centers are calculated, and all pixels into the subspace with the smallest distance are divided to achieve the clustering effect. Clustering distance can be defined as Euclidean distance:

$$\sqrt{(r_1 - r_0)^2 + (g_1 - g_0)^2 + (b_1 - b_0)^2} \tag{1}$$

The advantage of cluster-based color segmentation algorithm is that it has good local convergence and is more suitable for pixel classification in high-dimensional feature space. The disadvantages are also obvious. When there are unequal colors in the image, random selection of cluster centers can lead to misclassification. When the distribution information of each point shows the characteristics of the class, the image may be over-segmented, resulting in the segmentation effect not meeting the expected requirements, and even causing the segmentation to fail. The quadratic clustering algorithm is an iterative algorithm, which requires a large amount of computation and occupies too much CPU resources for high-resolution images.

3.4.4. Image Adaptive Color Segmentation Algorithm

Based on the advantages and disadvantages of the above algorithms, an adaptive color segmentation algorithm is proposed in this paper. The design idea of the adaptive color separation algorithm is to interpolate and scale the image after removing the black edge, and then retain the edge width of N pixels, and set the remaining pixels to 0 to reduce the processing time and impact on the final segmentation. The top, left and right edges of the image are processed. Taking the upper edge of the image as an example, the HSV color space component value of each pixel is obtained by looping. The conversion formula is as follows:

$$\begin{gathered} R' = R/255 \quad G' = G/255 \quad B' = B/255 \\ C_{max} = \max(R', G', B') \\ C_{min} = \min(R', G', B') \\ \Delta = C_{max} - C_{min} \end{gathered} \tag{2}$$

$$H = \begin{cases} 0^0 & , \Delta = 0 \\ 60^0 \times \left(\frac{G' - B'}{\Delta} + 0\right) & , Cmax = R' \\ 60^0 \times \left(\frac{B' - R'}{\Delta} + 2\right) & , Cmax = G' \\ 60^0 \times \left(\frac{R' - G'}{\Delta} + 4\right) & , C_{max} = B' \end{cases} \tag{3}$$

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases} \tag{4}$$

$$V = C_{max} \tag{5}$$

Pixels are classified according to the established HSV color space threshold table, and S sets are obtained. There are outliers and smaller subsets in the set. Then, the region fusion is performed to merge the outliers and the regions whose range is less than the threshold H, and finally obtain the continuous color interval set at the upper edge of the image. According to the color interval setting, map to the original image through coordinates and then segment the image. The detailed processing process is shown in Figure 5, and the experimental simulation results are shown in Figure 6.

3.5. Design and Implementation of Main Color Value Extraction Module

3.5.1. Extraction of Conventional Primary Color Samples

The main color extraction algorithm is also known as the color quantization algorithm, the main purpose is to select the most representative or common 256 colors from the approximately 16M colors that can be represented by a true color image. Common color quantization algorithms include median segmentation algorithm, octree algorithm [15], clustering algorithm [16], etc. Aiming at the large amount of color component data in true color images, this paper, and optimizes the median segmentation algorithm. The algorithm processing idea is shown in Figure 7: For RGB888 image data, each RGB color component occupies for 8 bits. If all are used, the number of recorded colors is about 16M color counter. In

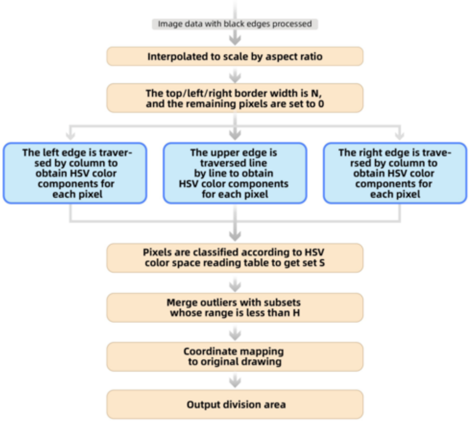


Figure 5. Hierar-DRL

Figure 6. Color Extension Diagram of Image Adaptive Color Segmentation Algorithm

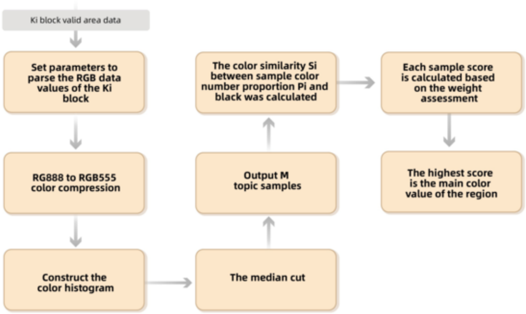


Figure 7. Extraction Process of Conventional Primary Color Sample

order to reduce the space occupied, this scheme compresses each RGB component into 5 bits, that is, RGB555 image data, so that the number of color counters is reduced to about 32Kb. Although precision is lost, the processing speed is greatly improved and the memory space of the program is used.

Before extracting the main color value samples, it needs to set the number of output theme color samples, which determines the final output theme color number in this area. The higher the number, the longer the processing time. In this scheme, the number of theme color samples is set to M. After the parameters are configured, the compressed RGB555 image data is processed, the color histogram is constructed to count the number of each color. The Median cut method is used to calculate the number of subject color samples.

The median segmentation method is to map all pixels into the RGB space, repeatedly slice the subspace in this three-dimensional space, and finally calculate the mean of the pixels in the segmentation space as the extraction result of the algorithm. Firstly, a spatial Cartesian coordinate system is established with three colors as the endpoints to ensure that all pixels are within the cube, and then set the median of the longest side of RGB in color statistics to 2, so that the two cuboids contain the same number of pixels. Next, repeat the above steps until the final number of cuboids equals the number of theme color samples. Finally, the average RGB color of each cuboid is calculated as the color value of the sample, and the number of cuboid samples is the number of main colors extracted from the area.

In this paper, the median segmentation method is optimized on the basis of a large number of experiments. According to the color frequency of the image and the distribution of color components in the color space, the cuboids in the color space is first sorted based on the maximum color difference, and the color mean of the components is selected as the dividing point instead of the median used for segmentation. In this way, the result obtained by the algorithm is more accurate, the color level of the image is richer, and there is no color failure. Based on the above operations, we obtain M color value samples in this area and the number of pixels for each color value sample in the area. The proportional value P of this color value in this area can be obtained by calculation.

$$P = \frac{Numberofcolorvaluepixels}{Numberoftotalcolorvalue} \tag{6}$$

The RGB values of M color samples and the pure black RGB value #ff000000 are respectively used for calculation, and the weighted Euclidean distance, that is, the color similarity, is calculated as follows.

$$\begin{gathered} \bar{r} = \frac{C_{1,R}+C_{2,R}}{2} \\ \Delta R = C_{1,R} - C_{2,R} \\ \Delta G = C_{1,G} - C_{2,G} \\ \Delta B = C_{1,B} - C_{2,B} \\ \Delta C \\ = \sqrt{\left(2+\frac{\bar{r}}{256}\right) \times \Delta R^2 + 4 \times \Delta G^2 + \left(2+\frac{255-\bar{r}}{256}\right) \times \Delta B^2} \\ s_i = \Delta C \end{gathered} \tag{7}$$

The larger the si value, the lower the similarity to black; the smaller the si value, the higher the similarity to black. This value can be used to evaluate the color contrast between subject colors. Finally, the similarity matrix is generated:

$$S = \begin{bmatrix} S11\ S12 \ldots S1m \\ S21\ S22 \ldots S2m \\ \ldots\ \ \ldots\ \ldots\ \ \ldots \\ Sn1\ Sn2 \ldots Snm \end{bmatrix} \tag{8}$$

N is the number of divided areas of the screen, and m is the number of subject samples in a single area.

After calculating the proportion and similarity of the theme color value in M, a two-dimensional space is constructed to calculate the weight according to the similarity S and the proportion P of the color value. The evaluation method is as follows:

$$Y = C_1 \times (S-\mu)^2 + C_2 \times S + C_3 \times P \tag{9}$$

Note: C_1, C_2, C_3, μ are constants, and μ value is the optimum similarity.

The one with the largest Y value among the M theme color samples are taken as the main color value of this area.

3.5.2. Extraction of Saltation Samples

To analyze the jumping color in the image, it is necessary to extract all the theme colors of the image, and judge the change of the number of pixels of the same theme color in each frame according to the analysis of multi-frame image data within a certain period of time. The color in which the number of pixels of the same color increases and changes the most in short period of time is regarded as the jumping color. In this paper, a skip color quantization algorithm based on multi-frame data fusion is proposed. The simulation test results are shown in Figure 8.

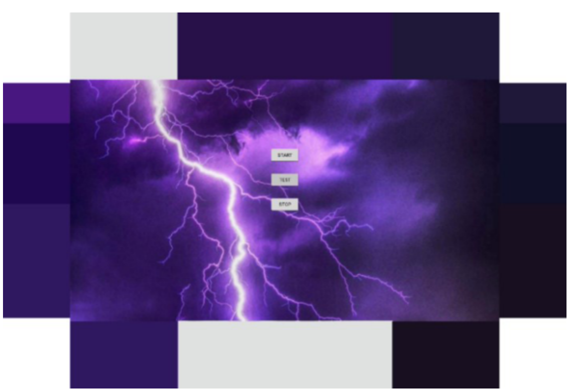


Figure 8. Schematic Diagram of Main Color Extraction Effect of Jump Color Change

4. Test Platform and Test Results

In this scheme, a debugging environment is built in the smart home laboratory. According to the design of the light strip, the light belt is fixed on the upper, lower, left and right sides of the back frame of the TV, and is connected to the same controllable network as the TV. The actual scenario is as follows in Figure 9.

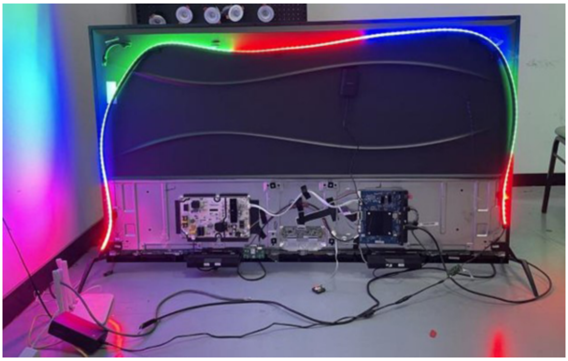


Figure 9. Display Diagram of Solid Light Belt

4.1. Hardware and Software Development Environment

The detailed parameters of flat-panel TV, LED symphony RGB light strip, TV and light strip are shown in Table 1 and 2.

Table 1.: Detailed Parameters for Flat-Screen TVs

Model	Casarte K65E50
operating system	Android 9.0 system
CPU	Cortex-A55 1.9GHZ
resolution	3840x2160
RAM	4G
ROM	64G
Refresh rate	60Hz

Table 2.: LED Phantom RGB Lamp Strip Detailed Parameters

Model	JRM70001
Operating voltage	DC12V
power	12.2W/m (white light).
Angle of light	120°
output	RGB
luminous flux	300lm./m
Lighting effects	25lm/W

The environment required for system software development is shown in Table 3 below.

4.2. Comparison of Algorithm Test Results

The four different algorithms in Section 2.5 are tested on the Intel(R) Core (TM) I7-8700 CPU hardware test platform, with 300 videos in the test set, and the average processing time of a single frame is compared as follows in Table 4.

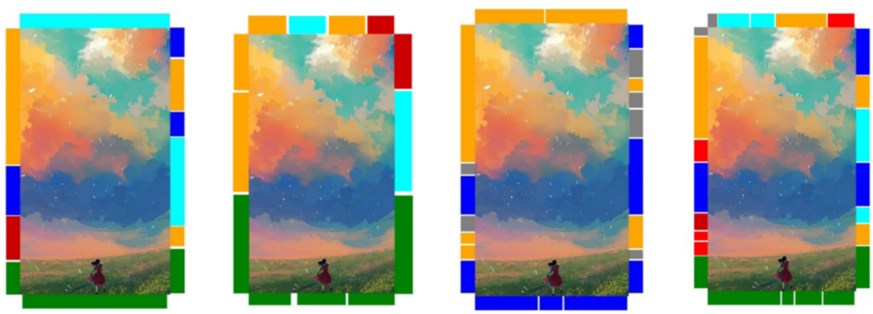
The color extension effect obtained by the four algorithms is shown in the Figure 10. The test team invited 10 people to evaluate and score 300 videos, and

Table 3. Software Development Environment

Development Environment	The Version Number
JDK Version	65 inches
Operating System	V1.8
Android Studio	V4.0

Table 4. Comparison of Processing Time of Segmentation Algorithms

Segmentation Algorithm	Time-Consuming Processing (Average single frame)
Segmentation algorithm based on regional growth	970ms
Based on threshold value segmentation algorithm	5ms
Based on clustering segmentation algorithm	1060ms(K=8)
Image adaptive color segmentation algorithm	23ms



(a) Color Extension of the Effect of Region Growing Segmentation Algorithm

(b) Color Extension of Threshold-Based Segmentation Algorithm Effects

(c) Color Extension Diagram of Clustering-Based Segmentation Algorithm Effect

(d) Color Extension of Image Adaptive Segmentation Algorithm

Figure 10. Color Extension Diagram Obtained By Four Algorithms

the subjective effect evaluation statistics are shown in Table 5. Threshold-based segmentation algorithms are the least time-consuming, but have poor subjective results. The algorithm with the best subjective effect are the clustering-based segmentation algorithm and the image adaptive color segmentation algorithm, but the clustering algorithm takes the most time. The adaptive color segmentation algorithm proposed in this paper achieves the desired effect with less time-consuming while taking into account the segmentation effect. In complex color scenes, the image adaptive color segmentation algorithm also performs well and can segment more color transformation domains.

Table 5. Evaluation Table of Subjective Effects of Segmentation Algorithms

Segmentation Algorithm	Subjective Experience (out of 10 out of 10)
Segmentation algorithm based on regional growth	6
Based on threshold value segmentation algorithm	5
Based on clustering segmentation algorithm	8
Image adaptive color segmentation algorithm	8

4.3. System Effect Display and Copy Test

At the TV side, the light and shadow effects can be switched on and off through the remote control. When it is turned off, the TV light strip is off and when the switch is turned on, it will automatically enter the light and shadow effect. The peripheral light strips will react according to the color of the TV screen as shown in Figure 11.

Figure 11. Display Renderings

The system has been continuously tested for 6 hours, and the average response time of the ribbon light and ribbon linkage is 40ms, which can capture the change of each frame of the video and meet the video requirements of 25 frames per second for ordinary network video. The actual test data is shown in Table 6.

Table 6. Copy Machine Test Data

Testing Phase	Total Number of Linkages	Average Time
2 hours	179,904	40.021ms
6 hours	539,020	40.073ms

5. Conclusions

5.1. Full Text Summary

This solution mainly realizes the synchronous linkage between the lighting equipment and the TV color in the life scene, and uses the image processing algorithm to extract the color of the TV screen, then controls the color of the lights to extend the TV picture to the surrounding environment to achieve the effect of color overflow. In the process of color extraction, image color segmentation algorithm, color shift and conventional main color extraction strategy algorithm are used. In terms of device networking connection, ZigBee technology and Bluetooth Mesh technology commonly used in the Internet of Things are used to form a controllable IoT network for each light strip device in the home. Finally, a smart home lighting scene linkage scheme with TV equipment as the core is realized. The solution does not rely on hardware boxes, has low cost, high flexibility, and does not affect TV picture quality. In the current era of rapid development of IOT smart home and emphasis on immersive feeling and experience, the system has a good prospect and use value. The system has the following advantages:

(1) Low cost. The cost of the hardware box is eliminated.

(2) High flexibility and easy expansion. If a new indicator belt device is added, it only needs to be configured on the network.

(3) It can play internal video source and external input video source, which is better than similar solutions in the market.

(4) The video is not compressed. This scheme adopts the strategy of displaying first and then processing, which has no effect on the video resolution.

(5) High stability and fast response.

5.2. Research Prospect

This paper focuses on TV equipment in smart homes, and introduces in detail the development and scene expansion of TV-based equipment, as well as the current technology applications between major brands. Through in-depth research on Internet of Things technology, image processing algorithm, ZigBee technology and Bluetooth Mesh technology, the optical linkage smart home system is realized. The system also has shortcomings. The first is the realization of system image acquisition, which relies too much on the method of chip manufacturers, cannot be used in other TV platforms and brand TV manufacturers, lacks versatility, so the image acquisition module needs to be adapted to the development. Secondly, the core of the system lies in image acquisition and algorithm processing, which also has certain requirements on the performance of TV equipment. The CPU must be above CortexA55 4 cores, otherwise the experience will be poor. The next step of the optical linkage smart home system is to optimize the image processing algorithm, decouple the software modules, and further improve the processing speed, so that it can still have a better visual experience on TV devices with low CPU.

References

[1] Ma Yi, Zhang Shangchao, Dai Hui, Xie Wenjun System and method for realizing audio and image synchronization control of light, Guangdong Province: cn113286405a, August 20, 2021

[2] Jin Wencan Multi lamp linkage music lighting system based on spectrum analysis , Hangzhou University of Electronic Science and technology, 2018

[3] Zhang Hao, Qiu Qinghua, Luo Xiaolong, Bi Cheng A method, device, system and storage medium for light following music rhythm, Guangdong Province: cn113133165a, July 16, 2021

[4] [4] Hong Chun. Bresenham circle drawing method to extract image information , Computer system application, 2014,23 (01): 128-131 + 27

[5] Zhou Feiyan, Jin Linpeng, Dong Jun. review of convolutional neural networks , Journal of computer science, 2017,40 (06): 1229-1251

[6] Zhou Junyu, Zhao Yanming. Overview of convolutional neural networks in image classification and target detection , Computer engineering and applications, 2017,53 (13): 34-41

[7] Jca B, Lei C C, Yz B, Cryptanalysis of a DNA-based image encryption scheme - ScienceDirect, Information Sciences, 520, 130-141(2020)

[8] Zhu Kaige, Wu Xiangjun, Ren Guanglong, Color image lossless encryption algorithm based on DNA dynamic coding and chaotic system, Computer application research, 37(S2), 230-233(2020)

[9] Zhang Jianwei, Quan Qingle. A plane segmentation method of dense point cloud integrating regional growth and RANSAC, Journal of Xi'an University of science and technology, 2022,42 (02): 341-348. Doi: 10.13800/j.cnki.xakjdxxb.2022.0219

[10] Wang Aichen, Zhang Min, Liu Qingshan, Wang Lili, Wei Xinhua. Extraction method of seedling crop rows based on regional growth mean shift clustering , Journal of agricultural engineering, 2021,37 (19): 202-210

[11] Niu Ying, Zhang Xun CAI, Image encryption based on variable step Joseph traversal and DNA dynamic coding, Journal of electronics and information, v.42 (06), 84-92(2020)

[12] Sun C, Wang E, Zhao B, Image Encryption Scheme with Compressed Sensing Based on a New Six-Dimensional Non-Degenerate Discrete Hyperchaotic System and Plaintext-Related Scrambling, Entropy, 23(3),291(2021)

[13] Ma Xiaoyu, Zhang Jinsheng, Li Ting, Image compression and encryption method based on Chua's circuit and compressed sensing, System engineering and electronic technology, 43(09), 2407-2412(2021)

[14] Es A, Rw B, Aks B, Securing color image transmission using compression-encryption model with dynamic key generator and efficient symmetric key distribution, Digital Communications and Networks, 2020

[15] Zhang Miao,Tong Xiaojun,Wang Zhu,Chen Penghui, Joint Lossless Image Compression and Encryption Scheme Based on CALIC and Hyperchaotic System, Entropy,23(8), 2021

[16] ZENG Jiexian, WANG Junting, FU Xiang. Multi-feature image retrieval method based on K-means clustering segmentation. Computer Engineering and Applications, 2013,49(2):226-230.