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Research of the Rice Image Segmentation Based on Color Linear Array CCD

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Abstract

Using color linear array CCD (Charge Coupled Device) to collect the information of image has an important meaning in the research of the machine vision processing. It now becomes the focus of study on CCD image acquisition using FPGA (Field Programmable Gate Array) to implement color linear array CCD-driven design. The image acquisition and processing of the rice color sorter as the research background in this paper, by using FPGA to achieve the color linear array CCD driven control, as well as simulated with Quartus II 8.0. In order to be able to extract the color linear array CCD output useful information of the color images, through study the RGB model and the HSI (Huge, Saturation, Intensity) model of color space model, the HSI space mode is selected as the color image processing space model, and design the suitable algorithm-FCM (Fuzzy C-Means) clustering algorithm in HSI space for color image segmentation, through a fuzzy Toolbox in MATLAB to accomplish the FCM algorithm, at the same time, through the simulation realized the FCM algorithm. The simulation shows that the algorithm can segment the image useful information well.

Keywords: *color linear array CCD; FPGA; HSI space; fuzzy c-means clustering*

1. Introduction

With the development of the social and economic, continuously improve of people's living standards; people are increasingly high demands for rice quality. This requires rice processing enterprises can be processed into high-quality rice; so the rice color sorting machine is widely used by food processing companies. The image sensor is a vision critical part of the color sorter, currently, the color sorter using black and white linear array CCD image sensor and color linear array CCD image sensor, and the drive controller always using CPLD, FPGA and DSP, *etc*. [1]. The color linear CCD image sensor can be easily carried on the motion separation and capture color images, it can obtain more surface color information of rice in rice sorting, so that it can enable better for rice sorting [2].

This article mainly focuses on rice image segmentation of color linear array CCD image sensor. Firstly, using FPGA as a driving controller of the color linear array CCD, controlling to produce the timing sequences that the color linear array CCD worked. Secondly, to process color image information collected by the color linear array CCD. In order to emphasize the characteristics of some interest in the image, such as edges, backgrounds, and null color, suppression is not interested in image features, to enhance the image and make it improve image quality and rich information content, enhanced image interpretation and recognition results [3]. Finally, we present a FCM algorithm approached that effectively segment the color image. With the adoption of the image segmentation algorithms on rice, it can accurately separate the image background, edge, and null color information about the target rice, achieve the goal of rice separation.

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2. Hardware Design

2.1. The System Framework Design

Hardware design of digital image data acquisition system is the basis of the image processing, digital imaging quality is the key to identifying. This paper designed a rice image acquisition system based on color linear array CCD. The image acquisition system used a modular design; it consists mainly of the following modules: optical detection module, signal processing module, digital signal processing module and PC processing module. The system framework figure is shown as Figure 1.

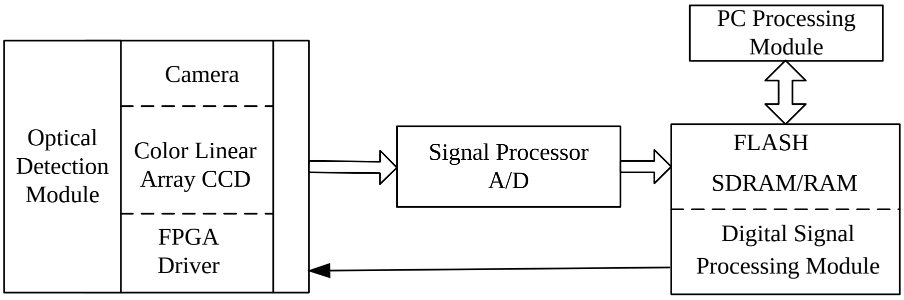

Figure 1. System Framework

In this paper, using FPGA to drive color linear array CCD and make it work properly in Optical detection module, the image information are collected by color linear array CCD will be output by R, G, and B value, through the AD module digitize the collection data, and then passes the processed signal to digital signal processing module. For the sake of facilitating the study of rice color image processing, the system making the rice information transmitted to the PC machine, researching and processing the rice color image over the PC machine.

In this paper, TCD2558D is chosen as a front image acquisition device, it is produced by TOSHIBA Company. Lens selection of linear camera series dedicated lens. AD9822 as signal processors, internal integration of correlated double sampling circuit is used exclusively for color CCD signal processing chip. EP2C5T144C8N is chosen as the primary hardware control chip of the image acquisition system, to achieve the TCD2558D and build a data cache. Finally the data are transmitted to the digital signal processing module. Construct the color linear array CCD image acquisition system; it is ready for further image processing.

2.2. The CCD River Module Design

TCD2558D is a high-sensitivity and low dark current color linear array CCD device. R, G, B three-column-sensitive units arranged in parallel, and monochrome as sensitive elements in each column is made up of 5,340 effective like the single channel sensing unit linear array CCD components. TCD2558D image sensor need five driving signals: transfer pulse SH, driver pulse CR1 and CR2 (CR2B), reset pulse RS and clamp pulse CP. Three color signals R, G, B output from the OS1, OS2, and OS3 port [4].

Because the TCD2558D sequential logic is driven by FPGA signal, TCD2558D driving voltage need 5V CMOS level, while the peripheral IO pin of the EP2C5T144C8N output level is 3.3V LVTTL, so we need to add a level conversion circuit (boost processing) to complete the conversion of CCD driver circuit. Input 5V CMOS devices compatible with 5V TTL level can be used as a 3.3V~5.5V level conversion. This is because the 3.3V CMOS level compatible with 5V TTL level, while CMOS output is always close to the power level. In this paper we select 74HC04 inverter as a level converter, while played his role of signal isolation, increased drive capability. Due to the choices in the design of the inverter as a level shift, so FPGA output drives CCD timing and timing signals to the contrary [5].

Through the analysis the timing diagram of TCD2558D, in the design we adopt Quartus II of the comprehensive PLD development software from Altera Company, which can realize the simulation of a sequence of image sensor. Because of using a inverter to process the voltage between the FPGA and the CCD, so the timing in FPGA output should work with CCD time sequence inverse relationship. CCD drivers are written by Verilog language. The CCD simulation waveform is shown as Figure 2.

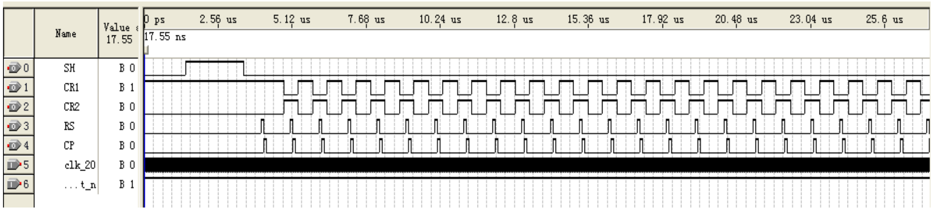

Figure 2. CCD Driver Simulation Waveform

3. Image Process

3.1. The Introduction of Color Space

In this paper later mainly introduces the RGB space and HSI space. In Real life, most of the visible colors can be represented by combining red, green, and blue colors, and color space model theory is derived from the color of the three primary colors theory. Select the red, green and blue as primary colors, Tri-phosphor luminance values are used to quantify the various colors, it is the more commonly used color information expressions. The RGB space model is shown of Figure 3. Figure 3 shows that any color in RGB color space can be represented by a point in three dimensional spaces.

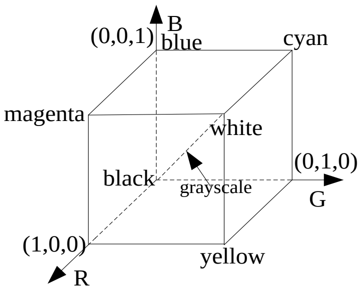

Figure 3. RGB Space Model

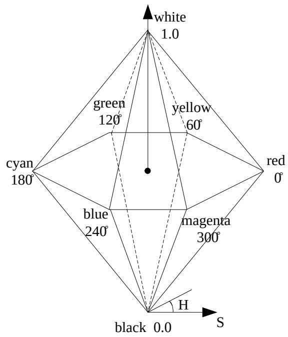

Figure 4. HSI Space Model

HSI color space model is described color feature by three parameters H, S, I, This space model can reflect people's sense of vision well on color. HSI space model is shown of Figure 4. H defines the color of the wavelength, known as hue, S represents the depth of the color is called saturation, and I say intensity or brightness. HSI color model using a double-Six pyramidal, solid color I values in the HSI color space is intermediate gray 0.5. I reflect the intensity of a color has nothing to do with concepts; it is suitable for color image processing.

HSI color space is not only visually describing the image colors, and can reduce the complexity of color image processing; this will speed up the speed of color image processing. In the processing of color image, even if it's just using a color model in which one component will also achieve a good result. Because of the three components of the HSI color model are easy to separation, and they are independent of each other, a lot algorithms used this space in image processing and computer vision.

HSI color space is obtained from RGB color space by nonlinear transformation. So formula (1) is the basic relationship through the RGB space to HSI space [6].

$$\theta = \arccos\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\} \quad (1)$$

The angle θ is mainly based on HSI space measured red shaft, shown in Figure 4. Then we can achieve the H, S, and I. Like formula (2), (3) and (4).

$$H = \begin{cases} \theta, & B \le G \\ 2\pi - \theta, & B > G \end{cases} \quad (2)$$

$$S = 1 - \frac{3}{R+G+B}[\min(R,G,B)] \quad (3)$$

$$I = \frac{1}{3}(R+G+B) \quad (4)$$

In the RGB space the component of R, G, and B have a high correlation, it is not suitable for color image processing space. Obtained by nonlinear transform in HSI space H, S, I three components are independent of each other, and then it is appropriate for color image processing space.

3.2. Design of the Fuzzy c-means Clustering Algorithm

Fuzzy c-means is a kind of segmentation algorithm for fuzzy clustering in image feature space, its realization is the objective function of the nonlinear double iteration method, the objective function by using the weighted similarity between the clustering center and the image of each pixel is measured. Its outer layers are used to determine whether the algorithm converges to a pre-set threshold, the inner layer is used to update the membership function matrix and calculate the new cluster centers. Eventually the objective function is minimized, obtained the appropriate cluster centers and membership matrix, to divide the sample, get the best results [7].

FCM algorithm design is primarily a sample set $X = \{x_1, x_2, \cdots, x_n\} \subset R^s$, s is the sample space of dimension, n is the sample number; c is the cluster of the sample division. FCM algorithm can be described as formula (5):

$$Min\ J_{fcm}(U,V) = \sum_{i=1}^{c} \sum_{j=1}^{n} u_{ij}^m d_{ij}^2 \quad (5)$$

Enable

$$\sum_{i=1}^{c} u_{ij} = 1, \quad 1 \le j \le n \quad (6)$$

$$\sum_{j=1}^{n} u_{ij} > 0, \quad 1 \le i \le c \tag{7}$$

$$u_{ij} > 0, \quad 1 \le i \le c, \quad 1 \le j \le n \tag{8}$$

From formula (5), we can know m>1 is fuzzy factor; $U = u_{ij}$ is a $c \times n$ fuzzy matrix, u_{ij} is the part of j sample, x_j belongs to the part of i membership degree; $V = [v_1, v_2, \cdots, v_c]$ is a $s \times c$ matrix that consist of c cluster center vector. $d_{ij} = \| x_j - v_i \|$ indicates the distance from the sample point x_j to the center v_i [8].

FCM algorithm design is mainly to set the number of clusters c and fuzzy-index m, initializing cluster centers $V^{(0)}$, set the precision of convergence ε >0, set the iterative number k=0. Using the formula (9) to calculate $U^{(k+1)}$, and in formula (9), i, j must satisfy formula (8).

$$u_{ij} = \left[\sum_{r=1}^{c} \left(\frac{d_{ij}}{d_{rj}} \right)^{\frac{2}{m-1}} \right]^{-1} \tag{9}$$

Using (10) to calculate $V^{(k+1)}$:

$$v_i = \frac{\sum_{j=1}^{n} (u_{ij})^m x_j}{\sum_{j=1}^{n} (u_{ij})^m} \qquad i = 1, 2, \ldots, c \tag{10}$$

Set k=k+1, repeat (9) and (10), until they meet (11) to terminate the operation.

$$\left\| V^{(k)} - V^{(k-1)} \right\| \le \varepsilon, \ k \ge 1 \tag{11}$$

3.3. Rice Image Enhancement Processing in HSI Space

Each pixel in the rice image information is described by the three RGB values, which collected by color linear array CCD. So, when we processed the rice image which collected by color CCD, we need to consider spatial information for image processing. Consider the environment have an impact on image information which collected by CCD, we have to enhance processing for the rice images before segmentation. The rice image in the RGB space is shown of Figure 5. Taking into account earlier design algorithm, the color space will convert from RGB space to HSI space for image processing through formula (1), (2), (3) and (4). To convert the rice image into the HSI space by MATLAB, the rice image in the HSI space is shown of Figure 6.

Figure 5. The Rice Image in the RGB Space

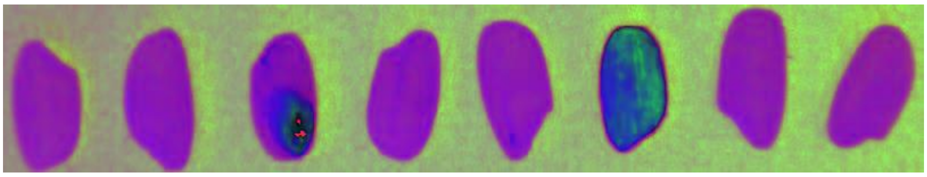

Figure 6. The Rice Image in the HSI Space

From the HSI image we can extract the H component; S component; I component of the rice image. The image is shown of Figure 7.

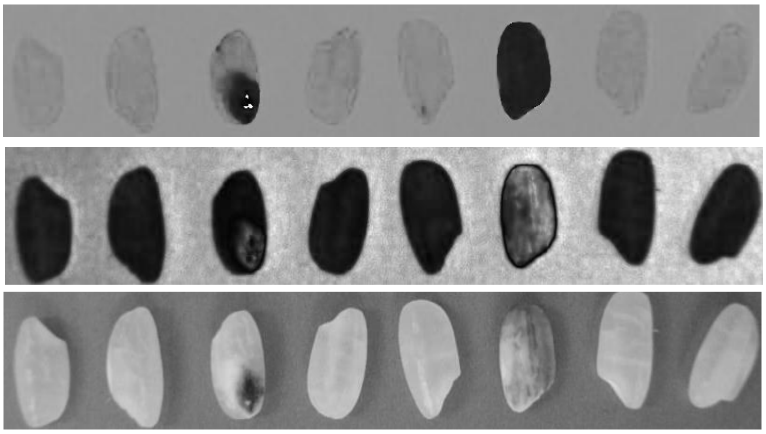

Figure 7. The H Component; S Component; I Component of HSI image

In order to view the probability of each component in the image grayscale pixel information, we observe the various components of the histogram in HSI space. The HSI and histogram image is shown of Figure 8. From the histogram we can see the probability of HSI components in the gray scale is not the same, the HSI histograms in a specific range of gray levels in the diagram have a larger proportion, and it is a disadvantage for the rice image segmentation.

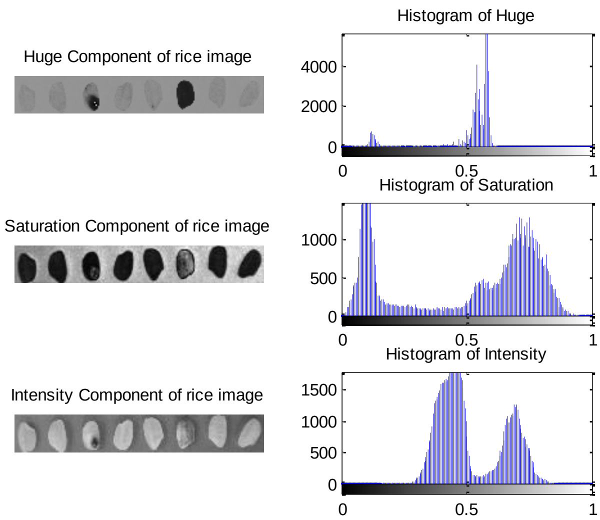

Figure 8. The HSI and Histogram Image

So we can obtain the image enhancement by histogram equalization of HSI component. The Equalization of the HSI component and its histogram is shown of Figure 9.

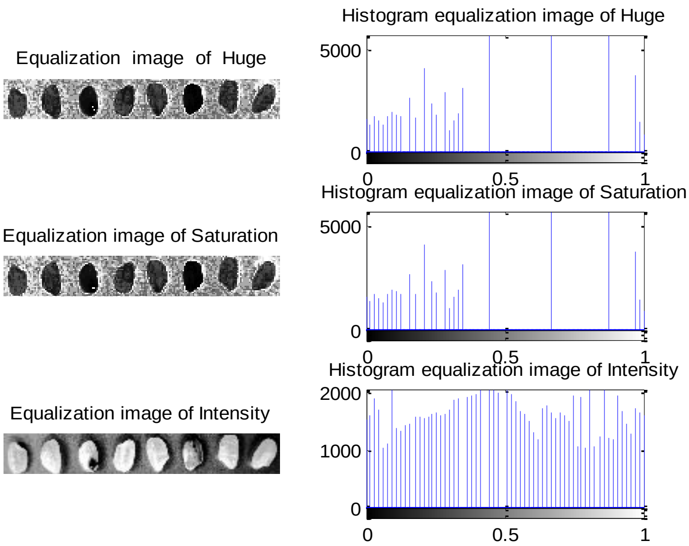

Figure 9. Equalization of the HSI Component and Histogram Image

3.4 Simulation and Verification of Rice Image Segmentation with FCM Algorithm

According to the formula (5), we should design the c value, because of we need divide the edge of the rice, image background, and the defect rice in the rice image, in this paper, the value of c is 3, the value of m is 2, from the formula (9), (10), and (11), set the objective function termination conditions is 10^{-5}. In the MATLAB environment, used the Fuzzy ToolBox tools to help design the FCM algorithm. The rice image is divided completely through the FCM algorithm. The edge of rice can divide clearly, it is shown of Figure 10. The background and defect of rice can spilt perfectly, it is shown of Figure 11.

Figure 10. The Edge Image of Rice Processed by Image Segmentation

Figure 11. The Background and Defect Image of Rice Processed by Image Segmentation

By the simulation of FCM algorithm in MATLAB, From Figure10, Figure11 we can observe this algorithm can divide the rice image well. The simulation results show that the algorithm completion time is not long; it is able to meet the requirement of rice color sorting for time in the experiment. From the simulation we know the cluster value of c is very important in this algorithm, if we can't ensure the value of c, we should spend more time in this algorithm, this is not conducive to the color sorter for real-time requirement.

4. Conclusion

In this paper, the image acquisition system based on color linear array CCD is designed. In the basic of studying the color linear array CCD, the CCD timing driver is designed by FPGA controller, the platform is built for color linear CCD image acquisition of rice. In order to be able to analyze rice image information better which collected by the CCD, Firstly, the color image information is converted from RGB space to HSI space for processing. Secondly, through the histogram equalization operation of the image to complete the rice image enhancement in HSI space. Finally, FCM algorithm is designed to complete rice image segmentation, and proved it by MATLAB simulation. The simulation results show that this algorithm can quickly and completely cutting out the edge, background information, and defect rice of rice image, the simulation has further proved the accuracy and validity of the algorithm design.

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