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Implementation of Edge Detection Based on Autofluorescence Endoscopic Image of Field Programmable Gate Array

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Abstract**—**Autofluorescence Imaging (AFI) is a technology for detecting early carcinogenesis of the gastrointestinal tract in recent years. Compared with traditional white light endoscopy (WLE), this technology greatly improves the detection accuracy of early carcinogenesis, because the colors of normal tissues are different from cancerous tissues. Thus, edge detection can distinguish them in grayscale images. In this paper, based on the traditional Sobel edge detection method, optimization has been performed on this method which considers the environment of the gastrointestinal, including adaptive threshold and morphological processing. All of the processes are implemented on our self-designed system based on the image sensor OV6930 and Field Programmable Gate Array (FPGA), The system can capture the gastrointestinal image taken by the lens in real time and detect edges. The final experiments verified the feasibility of our system and the effectiveness and accuracy of the edge detection algorithm.

Keywords**—**AFI, edge detection, adaptive threshold, morphological processing, OV6930, FPGA.

I. Introduction

THE basic principle of AFI technology is that some molecules in biological tissues, such as structural proteins and amino acids, can generate certain autofluorescence radiation signals under the excitation of certain wavelength of light, corresponding to the absorption of light [1]. This fluorescence phenomenon is not changed by the external light source, so it is called auto fluorescence. In the process of carcinogenesis, due to the decrease of glycoproteins and other substances on the cell membrane of the tissues, changes in cell morphology lead to changes in the distribution and concentration of fluorescent substances, blood concentrations, resulting in differences in autofluorescence signals [2].

Fig. 1 shows the principle of autofluorescence generation and the spectral and color differences between normal and cancerous tissues. We can conclude that the color and spectrum of autofluorescence images of normal and diseased tissues are significantly different [3].

For gastrointestinal images, the color of healthy gastrointestinal tract is similar and there are no obvious differences. But if there are some symptoms, the color will change clearly, which will be regarded as the edge in the gray scale image. Therefore, by using edge detection in gastrointestinal images, medical staff can extract lesion areas in the real-time video images of the gastrointestinal tract, thereby narrowing the scope of detection and improving the detection efficiency and the accuracy of location of disease [4], [5].

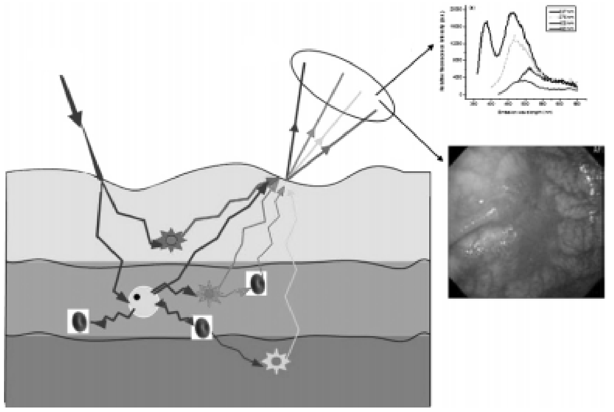

Fig. 1 Auto fluorescence spectrometry

This paper is organized as follows. Section I presents the background of this paper. Section II introduces the implementation of self-designed hardware of the system. Section III presents the principles of optimization particularly. Section IV shows the experimental results and the final section concludes the whole paper.

II. System Hardware

The overall structure of the system is shown in Fig. 2.

The whole system consists of 4 parts. In the front endoscopy, the image sensor, OV6930, provides analog images in RAW RGB format through the control of the Serial Camera Control Bus (SCCB). A short-focus lens is set on the front of the OV6930 to receiving reflected light from tissues. The lighting module is composed of two UV LEDs. The wavelengths of two LEDS are both 365nm which can excite the autofluorescence of the tissue. The A/D converter, OV420 converts the analog data to digital data using a built-in A/D converter (ADC). Then, integrated digital data will be transferred to FPGA, FPGA firstly captures input 8-bit RAW format image data, then FPGA will process image data including signal debounce, and morphology processing. After processing, FPGA transfer processed data to USB chip CY7C68013 by Slave FIFO. The USB chip will pack data to PC for display.

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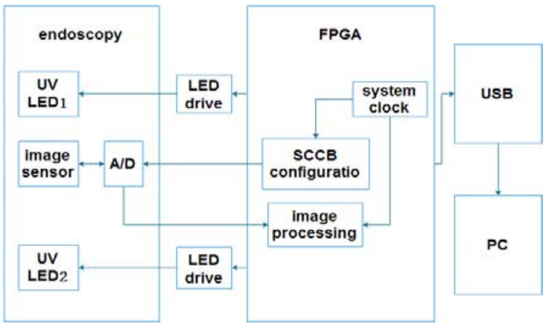


Fig. 2 The system structure

III. Optimization of Edge Detection

This section introduces the optimization including signal debounce, adaptive threshold implementation and erosion to improve image quality.

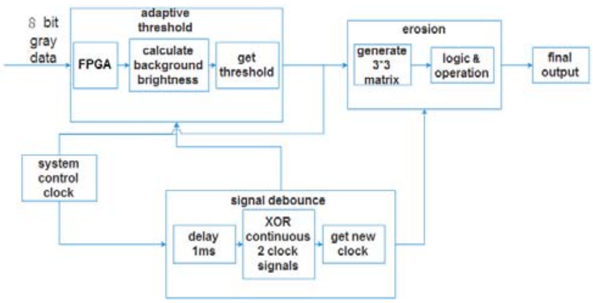


Fig. 3 The algorithm block diagram

A. Signal Debounce

There are multiple clocks in this system. For example, the input clock of the system is 24MHz produced by a crystal oscillator, the input drive clock of the OV6930 is 24MHz, and the pixel output clock signal is 12MHz. The input clock of the SCCB control module is 50MHz. Therefore, removing the jitter and glitch of the clock signal is necessary, although it will consume a certain amount of resources, but the stability will be greatly improved.

This paper uses edge detection techniques to determine if a clock signal jumps. Two consecutive clock signals are stored in two registers, and then calculate the result of their exclusive OR operation. If the result is 1, the clock jumps and an edge appear. If the result is 0, the clock signal does not change.

The design of signal debounce, on one hand, decreasing glitch of clock signal, on the hand, the error frame of the video image is also greatly improved.

B. Adaptive Threshold Implementation

When we study the brightness of the image, only if the difference of the grayscale value of two points reaches a certain value, the human eyes can distinguish these points. And we call this value JND. In different brightness backgrounds, the values of JND are also different [6]. The ideal curve of the relation of background brightness and brightness seen by human eyes is shown in Fig. 5.

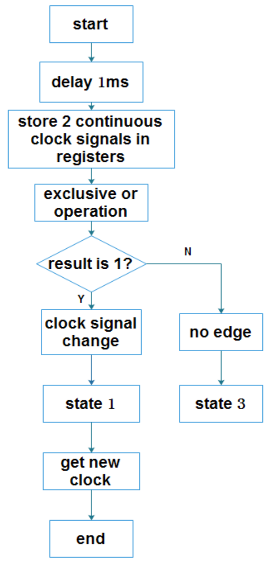


Fig. 4 The algorithm of signal debounce

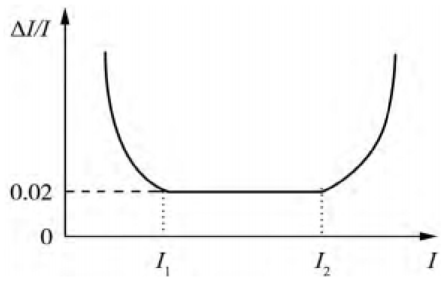


Fig. 5 The theoretical JND Curve

From Fig. 5, we can see that when the background brightness is too small($I<I_1$) or the background is too bright($I>I_2$), the brightness threshold ΔI that human can distinguish increases like an exponential curve, and when I is between I_1 and I_2, the JND curve approximates a constant which will be different in different environment [7].

In this paper, one point's background is the template centered on it whose size is n*n. The background is expressed by the gray average of its neighborhood points (In this paper, n=3). Based on the classical JND curves, after many calculations and simulations, the author gets a segmented representation model of gray image edge detection. The expression is shown as follows.

$$\Delta I = \begin{cases} 4.415e^{\frac{1}{0.141I+1}} (0 \le I \le 18) \\ 2.413 \times 10^{-6} I^3 + 6.667 \times 10^{-4} I^2 I + 6 (18 \le I \le 150) \\ 5.235e^{\frac{6.622}{256-I}} (150 \le I \le 250) \end{cases} \quad (1)$$

It is worth noting that the lower limit is only 18 and the higher limit is just 150, the reason is that the environment of the gastrointestinal tract is darker. Thus， according to above equations, we can get the optimized JND curve. (Units are all 1).

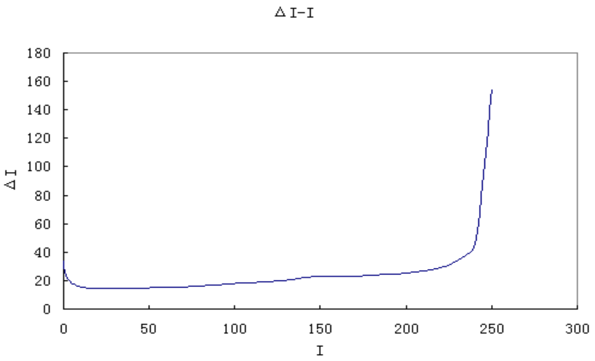


Fig. 6 The optimized JND curve

C. Erosion

Erosion is used to remove certain pixels from the edges of an object, which often used for edge detection; noise filtering and morphological skeleton extraction [4]. The erosion operation of algorithm is shown below.

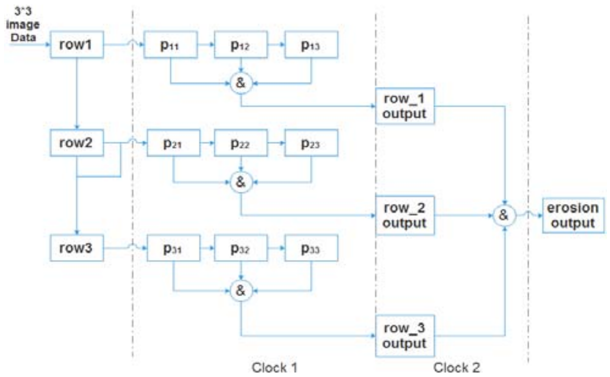


Fig. 7 Erosion algorithm diagram

For one center point, the size of its neighborhood matrix is 3*3, and only 2 clocks are needed to calculate the etched value of the center point, that is in first clock, the result of the AND operation of the 3 elements of each row separately will be get, and in second clock, output the final erosion result.

IV. Experiment Results

The experiment select split isolated large intestine of pigs as the experiment objects. And the author smeared the fluorescent agent on the intestine to simulate canceration, and then used the endoscopy to take images of the lesion areas in grayscale.

From Fig. 8, cancerous areas are shown in black who are clearly different from normal areas. And based on this, the step-by-step results of edge detection are shown in the following figures.

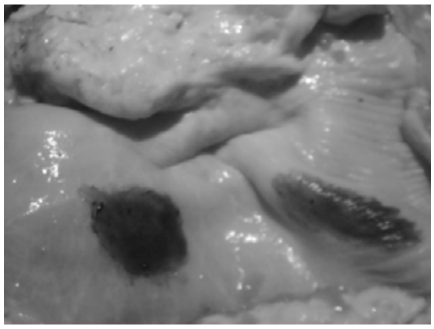
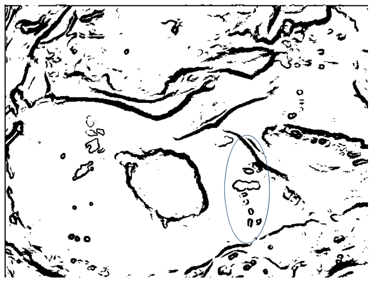


Fig. 8 Pig's large intestine's simulated lesions



(a)

(b)

(c)

Fig. 9 Experiment results (a) traditional Sobel method (b) adaptive threshold (c) erosion

A. Subjective Evaluation

There are many body fluids inside the gastrointestinal tract, so it will cause reflection when illuminated with an ultraviolet LED source. In Fig. 9, the blue ellipses are used to circle the most intense reflections. It can be seen that the results obtained by the traditional Sobel method have two marked areas in Fig. 9 (a), and after adaptive threshold processing, in Fig. 9 (b), more reflection areas are detected of the inner wall. After erosion, in Fig. 9 (c), the reflection is greatly weakened, and there is only one circle represent relatively blurred reflection.

Another important indicator of evaluation is the degree of refinement of the edges, which appears as the width of the edges in the image. In general, the thinner the edge detect, the better results are. In the upper part of the original picture, more shadows are formed because of the wrinkles, so the edges detected in first two images are generally thicker, but because of the erosion, a part of the pixels of the edge can be deleted, so the edges in Fig. 9 (c) are generally thinner.

B. Objective Evaluation

Edge continuity is an extremely important criterion for edge detection. The better the edge continuity is, the better the detection algorithm will be. And this paper uses the following approximate equations to detect the continuity of the detected results [8] of above images.

$$M = \frac{\sum_{i=1}^{m}(n_i \times C_i)}{\sum_{i=1}^{m} n_i} \quad (2)$$

$$C_i = \sum_{k=1}^{n_i} c_k \quad (3)$$

$$c_k = \begin{cases} d_k / D, d_k < D \\ 1, d_k \geq D \end{cases} \quad (4)$$

In above equations, m is the number of edges in the image, n_i represents the number of pixels in one edge, C_i is the sum of c_k which can be calculated by d_k and D. d_k represents the real distance from the point (x_k^i, y_k^i) on the edge to the center point of the edge, and D is the distance threshold which is set to 2 in this paper. Table I shows the edge continuity indicator of Fig. 9.

TABLE I
THE EDGE CONTINUITY RESULTS

	(a)	(b)	(c)
The total number of pixels	263752	250573	271079
The number of edges	178	215	94
Continuity results	0.4842	0.3447	0.7084

Those above test results are calculated by matlab. The same point is the numbers of pixels are all over 250000. Differently, the number of edges of Fig. 9 (b) is the most, resulting in the worst continuity results. And in contrast, though Fig. 9 (c) only has 94 edges, but the continuity indicator is 0.7084. However, the test results obtained are all not very satisfactory. The first reason may be the existence of wrinkles， and reflection should also influence the detection.

V. CONCLUSION

AFI technology can distinguish normal tissue and cancerous tissue according to color when detecting gastrointestinal tumors. In the grayscale image, the two tissues have the difference between black and white. Therefore, early cancer can also be detected using edge detection. In this paper, the image acquisition system based on image sensor OV6930 and FPGA was designed to test the isolated pig large intestine. The author used fluorescent agent to smear the inner wall of the large intestine to simulate the lesion. After converting the detected image into a grayscale image, it can be seen that the simulated lesion area has a clear boundary with the surrounding tissue. On this basis, the author has improved the edge detection algorithm. After signal debouncing, the adaptive processing of the threshold and the erosion operation, the detection results have been significantly improved. However, the detection results are not particularly desirable due to the presence of wrinkles on the inner wall of the large intestine and reflection of light. This is also where further optimization is needed in the future.

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