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Design of Fast Detection and Tracking System Based on FPGA

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Abstract. Aiming at the problem that the classical Sobel edge detection algorithm is sensitive to noise and has a large amount of computation, an adaptive fast edge detection algorithm is proposed. Firstly, some background information which we are not interested in is removed through adaptive window to reduce the computational complexity. Then, Sobel operator is used to detect the real-time edge of the image in the window, and then morphological optimization is carried out. The fast detection algorithm in this paper is implemented on the FPGA. The results show that this method can effectively detect image edges and make the image edges clearer. At the same time, it can greatly reduce the noise and computational load in the image and reduce the power consumption.

1. Introduction

Image is an important feature source for human eyes and computer to recognize image and obtain information[1]. Meanwhile, the edge of image is the most basic feature of image, which can help computer to recognize and understand image automatically. Image edge detection has been widely applied in the fields of aviation, military, medicine, artificial intelligence and other fields that need image processing. Because of the continuity of real-time target movement in image tracking, and we are usually not interested in the related aspects, we can reduce the computational complexity by reserving a search window and discarding other pixels after finding the target in the initial state, which not only reduces the consumption of hardware resources, but also reduces the power consumption.

Mathematical morphology is based on geometric theory and defines a set of transformations based on the set of structural elements. In image processing filtering, morphological filters filter the input image according to the shape of the object in the image. The relatively simple operation and moderate storage requirements of morphological filters make them the most frequently implemented image processing filters.

Traditional real-time image detection and tracking only use Sobel operator for edge processing[2]. However, whether it is to find a larger object or a smaller image object in a larger image, it needs to be calculated at all possible locations, and there is strong background noise. In this paper, Sobel edge detection [3][4] is used for real-time image acquisition by using FPGA to find the edge of the initial state, and then the size of the search window is automatically adjusted by the program to optimize the morphological filtering, and the edge image with clear edge is obtained.

2. System Overall Framework Design

The theory of linear filters is complete and relatively easy to implement, but these filters have difficulties in distinguishing the reasonable transformation of pixel values (such as edges) and abnormal changes caused by noise. But the nonlinear combination of linear filters can also provide more useful output than a simple filter. Sobel edge detection filter is a common and basic non-linear filter in the field of image processing. By utilizing the separability of the filter, a simpler implementation structure can be designed.

In order to get more fine edges, reduce noise interference, suppress background information, reduce computation and reduce power consumption, this paper uses the method of automatically adjusting the window size to determine the frame area which needs to calculate edges, and then carries out morphological optimization. The fast detection and tracking system based on FPGA is shown in Figure 1.

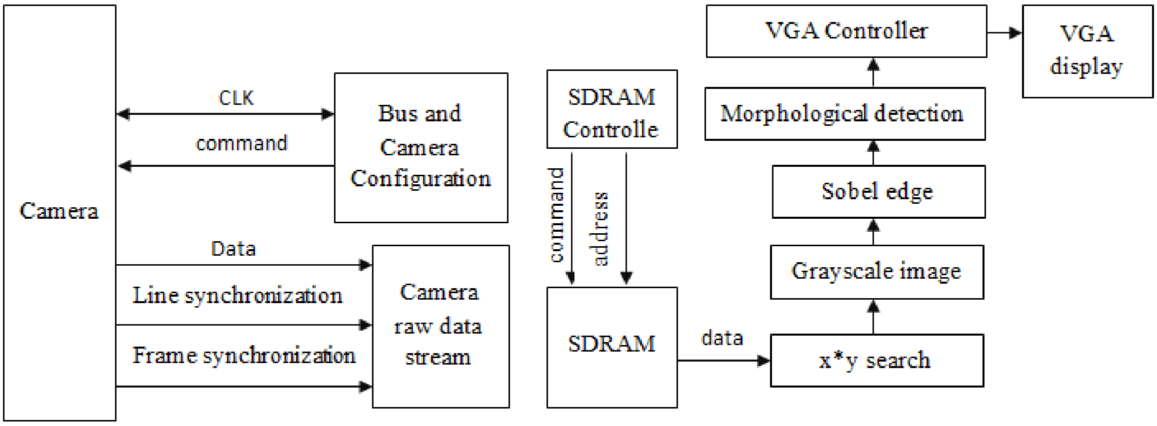

Figure 1. Design block diagram of fast detection and tracking system based on FPGA

3. Mathematical Morphology and Its Basic Operations

Based on set theory, mathematical morphology defines a set of transformations based on the set of structural elements. In image processing filter, the set is the pixel value of the image, and the structural element is considered as an arbitrary window. In binary images, pixels can be divided into two categories: target pixels and background images. Usually the target pixel is represented by 1, while the background pixel is represented by 0.

The basic operation of morphological filtering is corrosion and expansion. For corrosion, a target pixel is retained when the structural unit can be fully contained in the target. The structural unit is regarded as a window, and the output is the target pixel when all inputs are 1. Therefore, corrosion is the logic and function of the pixels in the window.

$$\begin{aligned} Q_{erosion}[x,y] &= I \Theta S \\ &= \wedge_{i,j\in s} I[x+i, y+j] \end{aligned}$$

It is called corrosion because the size of the target decreases as a result of the treatment.

For expansion, each input pixel is replaced by the shape of the structural unit in the output image. This is equivalent to the output of the target pixel when the flipped structure unit covers the target pixel in the input image. Expansion is the logic or the logic of the logical pixels in the window. Compared with corrosion, expansion enlarges the target and reduces the background. Corrosion and expansion are complementary, and the expansion of the target is equivalent to the corrosion of the background.

$$\begin{aligned} Q_{dilation}[x,y] &= I \oplus S \\ &= \vee_{i,j\in s} I[x-i, y-j] \end{aligned}$$

4. Implementation of Adaptive Window and Orphological Optimization

The improved algorithm first detects the Sobel edge based on the collected image which removes part of the background information, calculates the next window size, and optimizes the morphological corrosion and expansion of the corresponding edges of the large image. As shown in Figure 2.

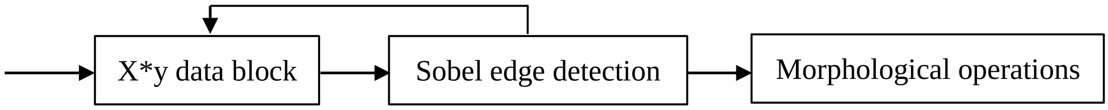

Figure 2. The block diagram of the algorithm in this paper

According to Sobel edge detection data, find out X_{max}, X_{min}, Y_{max}, Y_{min}. In this paper, CMOS outputs VGA(640×480 Resolution)At the time of Initialization, X_{max} =480, X_{min} =1, Y_{max} =640, Y_{min} =1. Since the edge detected by the edge detection operator has an error, and the target may be motion, in order to improve the accuracy, the window size may be preset, that is, the target tracking with the size of the target current position center x×y in the original image of size a×b is selected(a>x,b>y). And the detection, the size of the W sampled data block [5] is obtained, and the image data of the Sobel edge detection is required as the next frame image. The RTL-level schematic of the x×y adaptive window implementation is shown in Figure 3.

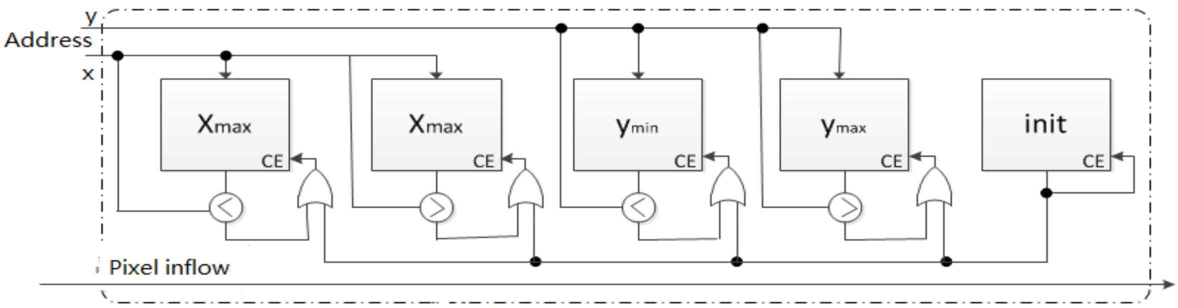

Figure 3. RTL-level schematic diagram of x×y adaptive window implementation

According to Xmax, Xmin, Ymax, Ymin, calculate the center position (centre) and size of the target, where

$$center = (\frac{x_{max} + x_{min}}{2}, \frac{y_{max} + y_{min}}{2})$$

$$size = (x, y) = (x_{max} - x_{min} + z, y_{max} - y_{min} + z)$$

In order to improve the accuracy and consider the motility of the target, this paper chooses Z=8.

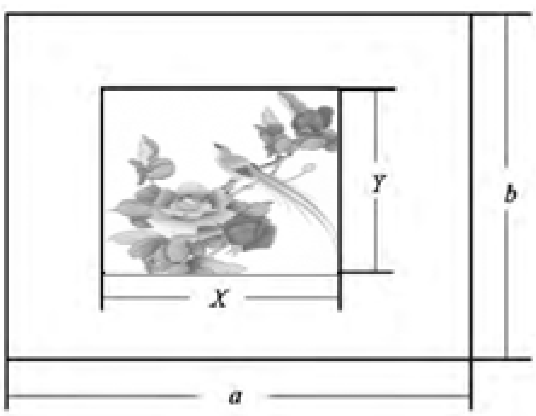

Figure 4. Schematic diagram of adaptive window downsampling

Downsampling the data block removes the background of the target image that we are not paying attention to, and the amount of data is greatly reduced, which is equivalent to the frame drawing and reduction processing of the metadata. The downsampled data block is grayed out and sent to the Sobel edge detection module. In the operation, the Sobel operator is used to convolute the image, and then the gradient formula is used to calculate the image gradient [6]. The multiplication and addition in the convolution operation is performed in parallel with the (programmable multipath parallel adder) in the macroblock library in the software [7].

After the Sobel operator detects the edge of the image, the data is sent to the morphological optimization module. P1~P9 are the edge data to be processed in the 3×3 operation template of the expansion or corrosion module. An implementation module for a morphological filter (corrosion or expansion operation) containing programmable structural elements is shown in Figure 4.

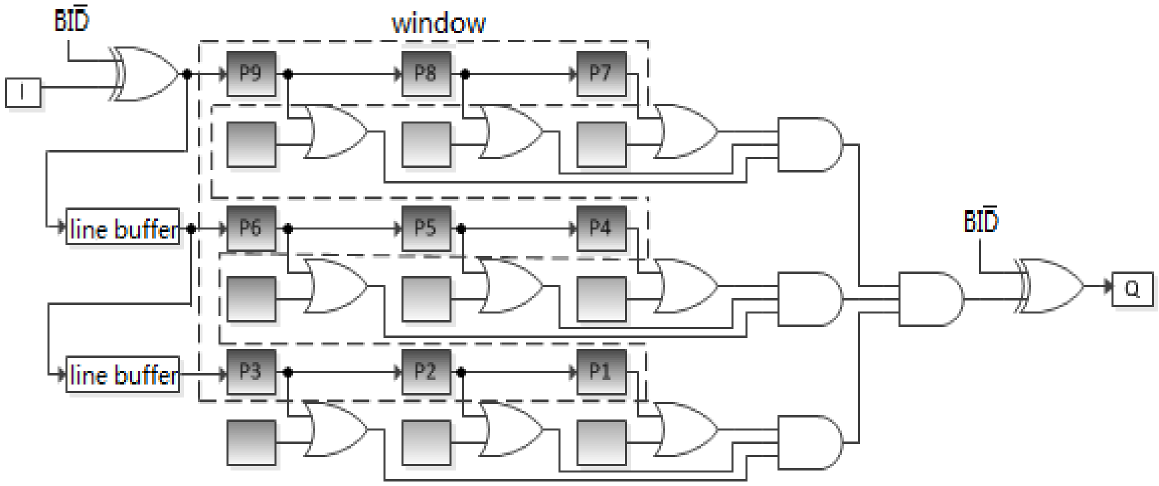

Figure 5. Schematic diagram of the corrosion and expansion morphology filter module

The complementarity of corrosion and expansion enables them to be realized in the same circuit. A control signal is used to compensate the input and output, and the control signal is used to select the operation of corrosion or expansion. Use an additional register associated with each window element to control the window element. When the window element is not a data block, the low level is used to shield the window data. For programmable windows, it is easier to share the control bits of the structural units than to operate the two window filters separately because of the morphological filtering of corrosion and expansion after edge detection.

5. Results and Analysis of Adaptive Window and Morphology Optimization

Figure 6 is the original image of the binary image, Figure 7 is the image detected by the Sobel algorithm, Figure 8 is the image optimized by the Sobel algorithm and then morphologically optimized, Figure 9 is the image detected by the algorithm, ie the improved algorithm the result of. From the comparison of Fig. 7, 8and 9, the algorithm is practical, the noise is suppressed after optimization, the edge is clearer, and the detection accuracy is obviously improved.

Figure 6. Original image before edge detection

Figure 7. Sobe edge detection

Figure 8. Sobel+ morphology optimization

Figure 9. Edge detection method

In this paper, the adaptive window is used to reduce the amount of data to be processed. Sobel edge detection is used to optimize the corrosion and expansion morphology. Finally, it is implemented on the FPGA platform with EP2C35F484C8N as the core. Compared with the traditional edge detection system, this method further reduces the calculation amount of background information, improves the processing speed, reduces the system power consumption, improves the accuracy of edge detection, and suppresses the background or is caused by the camera process. Part of the noise. It can be applied to areas such as monitoring, tracking, and aviation with high real-time performance, large amount of tasks, and large amount of calculation.

6. Acknowledgements

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