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Design and Implementation of Gradient Based Edge Detection Algorithm using FPGA

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ABSTRACT

The main aim of edge detection operation is a method to detect the presence of object image that commonly used in the field of image processing. The most well known technique for edge detection is gradient-based. There are number of methods that have been used to make an implementation of a gradient-based Edge detection algorithm design. This project proposes a design and implementation of gradient based edge detection algorithm using of Sobel & prewitt operator. Sobel operator is better noise suppression characteristics when compared to other operators such as Robert operator &2 order laplacian operator & others. An original image is converted into grayscale to obtain image intensity for edge detection. Sobel & prewitt operators are used for computing digital gradients. The whole process is performed in the hardware level. The result shows good performance of edge detection with which is able to detect just within 2ms.

Introduction

An edge can be defined as an abrupt change in brightness as we move from one pixel to its neighbor in an image. In digital image processing, each image is quantized into pixels. With gray-scale images, each pixel indicates the level of brightness of the image in a particular spot: 0 represents black, and with 8-bit pixels, 255 represent white. An edge is an abrupt change in the brightness (gray scale level) of the pixels.

Detecting edges is an important task in boundary detection, motion detection/estimation, texture analysis, segmentation, and object identification. Edge information for a particular pixel is obtained by exploring the brightness of pixels in the neighborhood of that pixel. If all of the pixels in the neighborhood have almost the same brightness, then there is probably no edge at that point. However, if some of the neighbors are much brighter than the others, then there is a probably an edge at that point.

Measuring the relative brightness of pixels in a neighborhood is mathematically analogous to calculating the derivative of brightness. So we approximate the derivative function. Different edge detection methods (Prewitt, Laplacian, Roberts, Sobel and Canny) use different discrete approximations of the derivative function. For example consider a random discrete 9 X 9 pixel image.

Edge detection is a very complex process affected by deterioration due to different level of noise. A number of operators are defined to solve the problem of edge detection. They are effective for certain classes of images, but not suitable for others. Edge detection is a crucial step in digital image processing. It has found application in artificial intelligence systems, forensic science and also in digital multimedia for creating image dazzling effect. Currently the image processing algorithms has been limited to software implementation which is slower due to the limited processor speed. So a dedicated hardware for edge detection has been required which was not possible until the advancements in VLSI technology.

Prewitt Edge Detector

A variety of Edge Detectors are available for detecting the edges in digital images. However, each detector has its own advantages and disadvantages. The basic idea behind edge detection is to find places in an image where the intensity changes rapidly. Based on this idea, an edge detector may either be based on the technique of locating the places where the first derivative of the intensity is greater in magnitude than a specified threshold or it may be based on the criterion to find places where the second derivative of the intensity has zero crossing. The basic criterion for using Prewitt edge detector for detection of edges in digital images is that image should contain sharp intensity transition and low noise of Poisson type is present.

When using Prewitt edge detection the image is convolved with a set of (in general 8) convolution kernels, each of which is sensitive to edges in a different orientation.

For each pixel the local edge gradient magnitude is estimated with the maximum response of all 8 kernels at this pixel location. It has been observed that the Prewitt Edge detector works well both with the Gaussian as well as Poisson noise corrupted images.

Further, it has been observed that out of the set two results, the performance of the said detector is much superior in Poisson noise corrupted image as compared to Gaussian noise corrupted image. However, its performance decrease drastically for Salt & Pepper as well as Speckle noise corrupted images. Prewitt edge detector by inherent does the

In this paper, an attempt is made to evaluate the performance of the Prewitt Edged Detector for noisy images. Experimental results have demonstrated that the Prewitt Edge Detector works quite well for digital images corrupted with Poisson Noise whereas its performance decreases sharply for other kinds of noise. Hence, this type of detector cannot be used in practical images which are generally corrupted with Gaussian noise, salt & pepper noise and speckle type of noise. However,

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these can be used successfully in conjunction with suitable digital filter to reduce the effect of noise substantially before applying the Prewitt Edged Detector. So, firstly noise is to be reduced by convolving the image with a suitable two dimensional digital filter. With the use of Digital Filter Isolated noise points and small structures are filtered out. Therefore, some filter for noise reduction has to be applied before applying Prewitt Edge Detector (PED) otherwise edge detection will not be accurate.

VLSI Implementation of an Edge Detector Based On Sobel Operator

This paper present the design and implementation of the Sobel operator in an application specific integrated circuit. Systolic processor arrays were employed for an efficient exploitation of the advantages of VLSI technology. The architecture obtained is highly regular and simple. The performance of the architecture is improved by means of the use of carry save arithmetic. The chap was implemented using 1 p mCMOS technology and the final area is10nam2. The resulting chip provides the values for the pixels of the gradient images (rows and columns) alternatively each clock cycle with a 20 cycle latency. The maximum operating frequency is 50 MHz and, consequently, it is an adequate design for real time image processing.

The great advantages of VLSI technology with regard to obtaining high performances with low area and power requirements make it attractive for the implementation of complex image processing algorithms in a single chip. Among them we find algorithms for edge detection. These algorithms are based on the detection of discontinuities in the values of the grey levels of the image. One of the most widely used techniques is the generation of a differential image by means of Sobel operator [1]. The characteristics of this operator, regularity, simplicity and efficiency, make it adequate for its implementation in an application specific architecture. Sobel operator is based on the differential approach to edge detection. With this approach, a Differential image G is generated from the original image F, where the changes in grey levels are accentuated. After this, the edges are detected by means of the comparison of the amplitude values to a predefined threshold level.

The differential image is generated from the gradient along the normal to the slope of the edge this gradient can be expressed as a function of the row arid column gradients, GR and

Gc, = GR(j k,) cosO + Gc(j, k) sinO (1)

Where (j,k) are the coordinates of the pixel of the image, F(j,k) is the value of the grey level of this pixelin the original image, G(j,k) is the grey level in the edge to the horizontal axis. The amplitude of the gradient and the orientation of the normal to the edge with respect to the horizontal axis are given by gradient image and 0 is the angle from the normal to the implementation of those equations implies a very high level of hardware complexity and are thus approximated by the difference between the methods employed lays in the approximation used for the generation of the values for GR and Gc. The row (G'e) and column (Gc gradient images are generate 6 with convolution images I s: where HR and H c are the row and column convolution masks respectively his is translated into a linear combination of pixelsin a small neighborhood of the pixel over which the gradients are calculated.

In this paper we present the VLSI implementation of a systolic architecture for the computation of the Sobel operator on N x N images. We have developed the high regular architecture with redundant (carry save) arithmetic. The architecture is implemented in 1pm CMOS technology. The chip area is 10nun2 ant! The maximum operating frequency is 50 MHz. These characteristics make the chip obtained adequate for real time image processing.

A high speed subpixel edge detector implementation inside a FPGA

In this paper, I am present a field programmable gate array (FPGA) implementation of a real-time subpixel edge detector. In comparison to existing edge detectors, the proposed method is implemented in hardware and its computational cost and complexity are very low. This in turn reduces the overall system cost quite significantly. The edge detection method is based on the approximation of the edge profile with a first-order linear function and then extrapolating the line to intercept a constant function.

The position where both lines intersect will be the edge position. The detector is capable of processing a high-resolution CCD linear sensor at 2000 frames/s at the maximum clock rate of the sensor of 2 MHz. For that reason it is as fast as an analogue approach. The experimental results show that the proposed method can increase the resolution of an existing intelligent line camera by a factor of 6 or more. From the above it can be concluded that the proposed edge detector is effective for real-time, low-cost subpixel edge detection.

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This paper compares several methods of computing the locations of edges (or lines) in an image to subpixel accuracy. It is found that methods taking the intensities of the edge pixels into account yield little or no improvement over a simple method of least-squares estimation based only on the locations of these pixels.

This paper describes an analogue-based approach to subpixel-level edge detection for dimension measurement and object localization. Although the most common subpixel edge detection methods employ digital-based approaches, at present they show certain drawbacks such as the difficulty of real-time, in-line subpixel edge detection, the necessity of implementing expensive high-resolution A/D converters, and difficulty in performing continuous, dynamic subpixel edge detection.

These drawbacks present a difficult problem in digital-based systems industrial applications. We propose a new analogue-based first derivative subpixel edge detection approach to overcome these drawbacks. Our method involves the approximation of the distribution curve of the first derivative of the output of a CCD by using the second-order polynomial, and thus can accurately detect a peak position of the differential curve by means of the interpolating calculation, the operation of which is realized primarily through the use of analogue circuitry. The measurements of a concrete form using the prototype system demonstrate that its resolution under ideal conditions is about 1 x 10-1 pixels. While the resolution of this system decreases in an actual situation, the resolution remains at an acceptable subpixel level. We thereby conclude that the approach described in this project is effective for real-time, low cost edge detection.

Edge Detection Algorithm – Description

Gradient edge detection operator is based on first derivative based operation. This operation is as shown in Fig.1. The algorithms of first derivative or first difference based operator are the simplest one that is why it is selected for implementation on hardware device. Consider u(p,q) be the two dimensional edge segment. We know that orthogonal edge gradient can be formed by running difference of pixels in horizontal and vertical direction. It is defined in magnitude form as the sum of the magnitudes of vertical and horizontal gradient.

Horizontal

The input of image to be consider as a 3 x 3 image when the 3 x 3 image the pixel values to be read. The algorithm shows the equation for calculating the horizontal part. Depending upon the pixel value the operation to be performed and the gradient of horizontal value.

Vertical

The input of image to be consider as a 3 x 3 image when the 3 x 3 image the pixel values to be read. The algorithm shows the equation for calculating the vertical part. Depending upon the pixel value the operation to be performed and the gradient of vertical value.

Combine

The result from the horizontal and vertical part we combine both of them. (ie) The summation output to be performed in combine block. The edge detection operator (Roberts, Prewitt, Sobel for example) returns a value for the first derivative in the horizontal direction (Gy) and the vertical direction (Gx). From this the edge gradient and direction can be determined:

$$G = SQRT\,(G_x^2 + G_y^2)$$

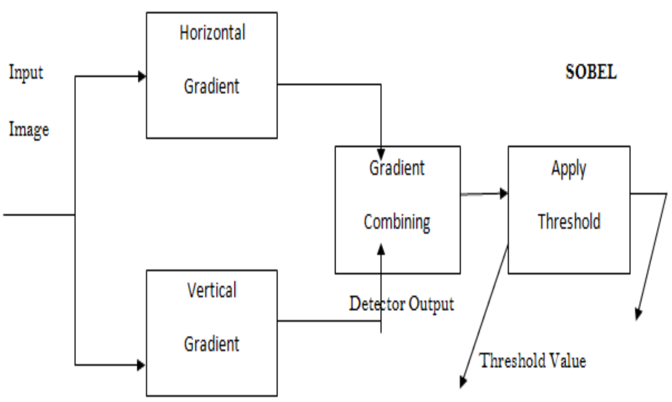

Fig: 3.1 Sobel Edge Detection Algorithm

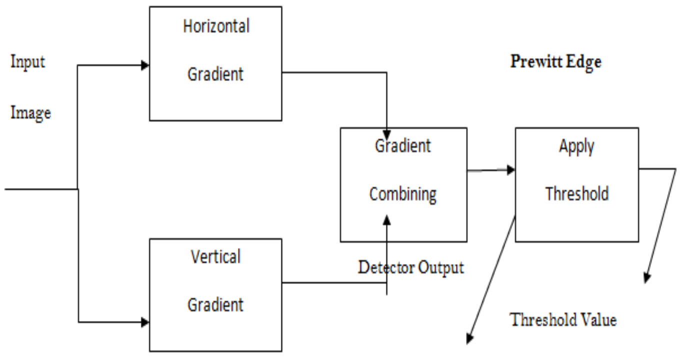

Fig: 3.2 Prewitt Edge Detection Algorithm

Threshold

Depending upon the threshold value the edge of the image to be processed. The output of the combine module we set the threshold range depends upon the value we set. The final output pixel value will be stored.

Gradient Operators

There are numerous edge operators available. Present gradient operators as a measure of edge sheerness can be divided into three categories.

1. Operators approximating the derivatives of the image function using finite differences (e.g. Roberts, Prewitt, Sobel, Laplace, Robinson, Kirsh, Compass edge operators).
2. Operators based on the zero crossings of the second derivatives of the image function (e.g. Marr-Hildreth or Zero Crossing, Laplacian of Gaussian, Canny edge detector) and
3. Operators which attempt to match an image function to a parametric model of edges (parametric operators).

Gradient operators are based on the idea of using the first or second derivative of the gray level. The first derivative will mark edge points, with steeper gray level changes providing stronger edge points (large magnitudes). The second derivative returns two impulses, one on either side of the edge. An advantage of this is that if a line is drawn between the two impulses the position where this line crosses the zero axis is the center of the edge, which theoretically allows us to measure edge location to sub-pixel accuracy. Sub-pixel accuracy refers to the fact that zero-crossing may be at fractional pixel distance. In the traditional edge detector, the gradient of image is calculated using first order derivation.

Prewitt Operator

The Prewitt operator is defined by eight convolution masks of 3x3 coefficients corresponding to the image orientation in the eight compass directions. It is possible to extend the mask beyond 3x3 coefficients, but it reduces the fidelity of the final edge image and increases the computation time. The Prewitt operator, similarly to the Sobel, and some other operators, approximates the first derivative.

Advantages of Edge Detection

The classical operator such as Sobel, and Prewitt which uses first derivative has very simple calculation to detect the edges and their orientations but has inaccurate detection sensitivity in case of noise. Laplacian of Gaussian (LOG) operator is represented as another type of edge detection operator which us second derivative. It finds the correct places of edges and testing wider area around the pixel. The disadvantages of LOG operator is that it can not find the orientation of edge because of using the Laplacian filter. The other type of edge detection operator is the Gaussian edge detectors such as Canny, Sh Castan and Boie-Cox operators which are using probability for finding error rate and localization. Also it is symmetric along the edge and reduces the noise by smoothing the image. So it is performs the better detection in noise condition but unfortunately it has complex computing.

Applications

- Remote sensering via satellites and other space crafts.
- Image transmission and storage for business applications.
- Medical processing.
- Robotics.
- Automated inspection of industrial applications.

Conclusion

The various aspects of gradient operator have been studied in detail. The project describe the gradient based edge detection algorithm using sobel & prewitt operator. In Phase-I the algorithm using gradient operators such as sobel and prewitt are developed using verilog and the comparison of sobel and prewitt are studied.

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