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FPGA based Hardback Conceptualization for Pothole Detection

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***Abstract*—Edge detection forms the primary path for any object detection which in turn is a capital part of image segmentation in the procedure of object detection, feature extraction and so on. Edge signals the extremity between overlapping or adjacent objects. An edge is also an extremity between an object and the backgroundd, hence by identifying the edges accurately it will be easier for the extraction of the information regarding measuring of area, perimeter and shape. In the direction of pothole detection few existing methods like ranging sensors of high maintenance or usage of acceleration data is expensive and also not very accurate in providing the database of the pothole. The pothole detection using image processing will help in alerting the driver and turning away from the same.The data of edge detection is very large, so the accomplishment of the high speed of image processing is a challenging task. Here various edge detection algorithmic rules are implemented on pothole images with many constraints and compared for narrowing down to the most efficient edge detector for pothole images. Field Programmable Gate Array (FPGA) can surmount this difficult task and it is an promising device to realize real-time collateral processing for vast amounts of image and video data. The proposed work pretense the exploitation of Prewitt edge detection algorithm on FPGA for pothole application.**

***Index Terms*— Field Programmable Gate Array (FPGA), Video Graphics Array (VGA), Pothole, Edge detection and Image segmentation.**

I. INTRODUCTION

With increasing in the human population, there is similar increase in the vehicular population as a result the road conditions have turned a huge mishap and due to decrease in maintenance of these vehicles during traffic and maintenance of roads there is a cause for damages of the road stead and major potholes. This is leading to major injuries to people and even killing a ample number of people. Also there is a large damage to the vehicles due to crashes which leads to economic loss. Basically due to the bad infrastructure of the roads leads to such mishaps and accidents on roads which depend on the condition of roads even. In every day live while traveling many potholes on roads are seen, the clarity to the driver is not given properly about the pothole, if it's not marked by sign boards. As approached towards potholes the assessment of the same as large and deep potholes may go unnoticed to the driver due to the speed which may the primary concern for the driver to change the path or laggard the vehicle. Negligence or overlook of such road hazards may lead to loss of human life. In the developing

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countries like India the road mishaps are not uncommon, hence the automated findings of such road problems need to be addressed. Some remote areas or places will not display the sign boards during such scenario the driver may find very unexpected accidents or other related problematic issues. Real-time quantifiable pothole data analysis is one of the epochal step for any modern transport system. The description about hardback image processing algorithms together with their outcome is produced, which administer a qualitative description to a road problematic issues like pothole.

Edge detection is one of the most basic and to be prioritized region in lower tier image processing. Edge detection assessment in assisting the driver plays a very critical role in designing the automated computer or machine vision systems. Different edge detectors focus on different attributes of image applications. The response of applied edge operators may vary from outcomes produced. The gradient operators are more susceptible to noise and ease of implementing compared to the Sobel operator. But the accuracy may be the matter of concern in the Sobel operator.

Edge detection may be detection of arch like edge segments called edgels, aggregation of arch like edge segments into prolonged edges may be parametric description.

II. Proposed System Approach

Edge operators helps in localizing pixel intensity extremities. The edge detection operators are used as most desired part of image processing like tracking, segmentation and so on. There mainly exists several edge operators (Sobel, Prewitt, Roberts,Canny). All the edge operators referred aim at detecting the extremities lying at the edges. The first approach of finding the edge extremities were done using gradient operators which is further classified into first and second derivative operators.

The gradient is assessed in all the directions and later computed considering all the gradient of different directions.

A Prewitt Edge Detection

The Prewitt operator is well versed in identifying the edges extremities which are vertical and horizontal in nature. This approach provides information about the magnitude and orientation of an edge of an image. But the method is limited for only eight achievable directions, despite almost all absolute directions evaluation may not be completely correct. This operator is calculated in an 3 x 3 neighborhood for 8 planes. One of the larger module among all the eight masks is selected as the edge. The core block is implemented by the below given arithmetical equation.In pothole detection the image is segmented in addition, area is obtained from the black clusters. The dark area represents the potholes. Hence by default where ever potholes are present it comes under dark area. The HT maps the few input feature to output space parameters. The Lane Detection process through Hough Transformation is done by detecting curves to find out the line separating an image. Joining these dots and imposing on points joining the captured image. Thus the above experiment was successful in detection the lanes, potholes and the sign boards on the road by the vehicle.

$$G = (A6+cA5+A4) –(A0+cA1+A2)+(A2+cA3+A4)-(A0+cA3+A4) \quad (1)$$

The operation of Prewitt detection is similar to the Sobel detector yet they have different core. The Figure 2.1 represents the 3 cross 3 convolution mask applied for calculating the X and Y gradients. This is the hasty way for edge calculation. This is best advisable for images without noise.

$$x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

Figure 2.1 Masks of Prewitt Edge Detector

The gradient value Gx and Gy are calculated separately by applying the input image distinctly to the core in both directions. Both the values are then added to get the absolute magnitude value at every pixel and inclination of gradient.The calculation of magnitude of gradient is done by:

$$G=|Gx|+|Gy| \quad (2)$$

The computational time is much less here. Inclination angle of the edge is calculated by equation below which represents the gradient value even.

Q=tan-1(Gy/Gx)
(3)

B. Sobel Edge Detection

A simple curve/edge calculation is done by Sobel operation which works based on pixels. By computing the part of output values of the 3 cross 3 neighboring pixels the edge is detected. Main advantage of this method is, it can process the noisy images easily and even has smaller masks on image. Figure 2.2 represents the convoluted matrix, the second matrix is just 900 rotation of the first. The curves moving in X-axis and Y-axis associated with pixel values are detected using the above kernel, for a pair of every perpendicular direction. The total gradient magnitude at every pixel is obtained by summing the gradient value obtained, when the kernel is applied separately for every pixel of input images. The gradient and magnitude calculation is similar to that of the Prewitt edge detection masks and equations.

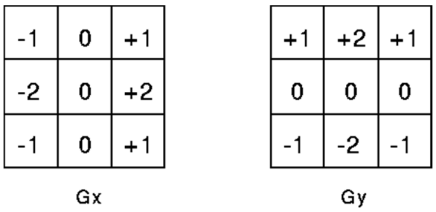

Figure 2.2 Masks of Sobel Edge Detection operator

C. Canny Edge Detection

Canny detector is insensitive to noise hence computes effectively the gradient magnitude and directions. It assures minimal response applying non-maximal suppression. Canny detector make use of physical phenomenon and property analysis to detect edges. In C-operator streaking near the threshold value should be avoided. This avoidance is done by defining two thresholds L and H. If less than L, it is decide as not an edge. If greater than H, it is decided as strong edge. In case the threshold value lies in between L and H then the edge is defined as weak edge. In the non-maximal suppression the edge occurs where gradient reaches a maxima. The maxima of all the pixel values in all the directions are checked (Only eight directions are possible) to suppress. Such suppression action is performed in each neighborhood pixel marked.

Canny edge detector is the most strictly defined operator and is widely used. It smoothens the image with appropriate Gaussian filter to reduce desired image. And it also determines Gradient attributes(magnitude and direction) at each pixel. The Canny edge detection operator is standard method used in many image applications used in industry. The important notice to be done is that the response should be obtained only at the edge extremities and no response should be obtained when at no edge extremities.

The distance between the detectors edge pixels and that of its actual edge should be maintained minimum. Further the attention should be given to find only one single response at a single edge avoiding the multiple responses at the single edge.Based on these criteria, the canny edge detector first smoothens the image to eliminate noise. The image gradient is found and the mark the regions with sensibly high spatial derivatives.

C. Robert Edge Detection

The Roberts operator performs an easy, quick to compute gradient measurement on an image. The format preferred at the input and the output should be in gray scale. In theory, the operator contains a set of 2×2 convolution masks as shown in Figure 3.One mask is merely the other rotated by 90°.That is very similar to the Sobel operator.

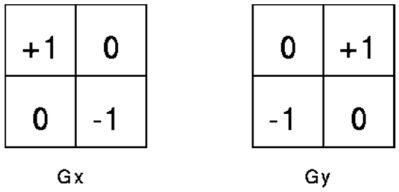

Figure 2.3 Robert mask for edge

III. Comparison of Edge Detection Algorithms

The Figure 3.1 depicts comparison of various edge detection algorithm applied on pothole image for the pothole detection application under various constraints.

The observations inferred from the Figure. 3.1 reveals that the canny edge detector is very sensitive and does not contribute to the pothole images edge detection efficiently comparatively. Robert operator seems to be better than the canny. Sobel and Prewitt operator seems to produce similar outcome of pothole edge detection effectively and efficiently under various constraints compared to canny and Robert operator.

Compared to Sobel, the Prewitt edge detection operator exhibits efficient execution time when statistical measurements are performed. Also the Prewitt operator is little simpler compared to Sobel operator.

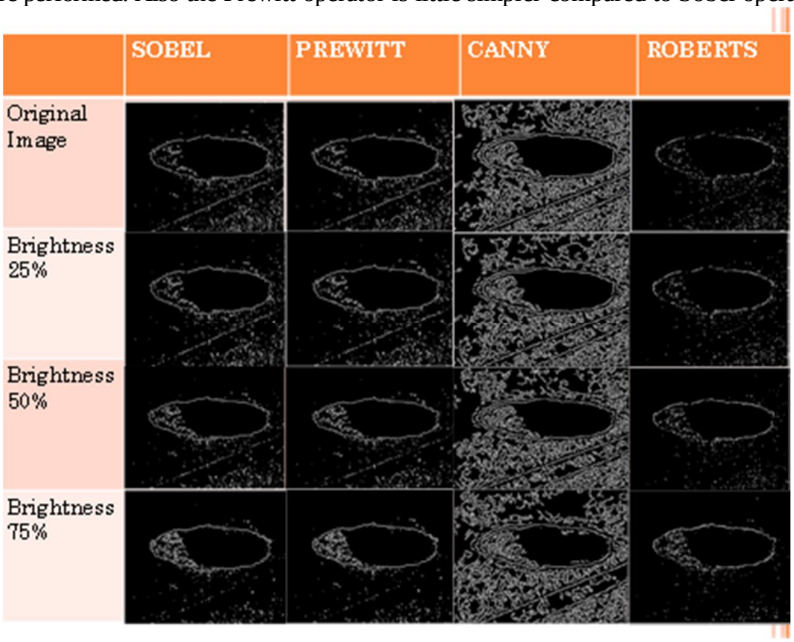

Figure 3.1a comparison of edge detection operators over different constrained pothole image

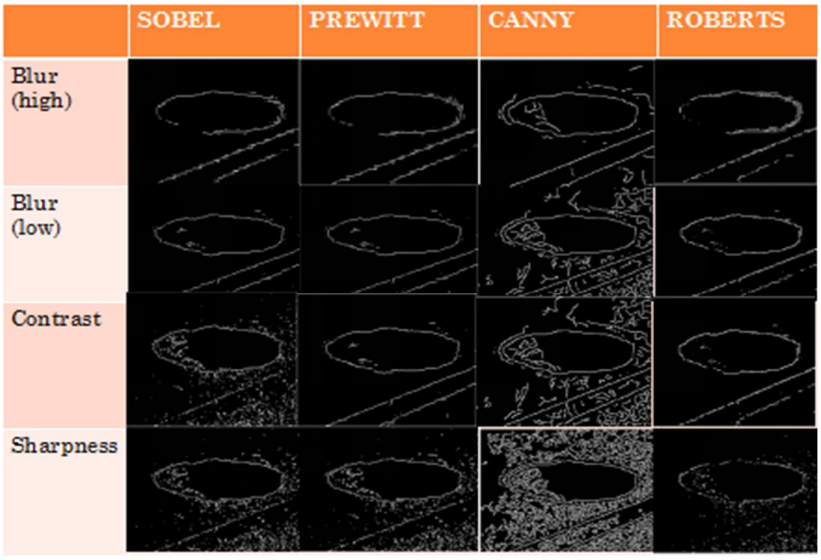

Figure 3.1b comparison of edge detection operators over different constrained pothole image

IV. Experimental Results

In MATLAB Simulation Results the Pixel output values are saved as text file values in MATLAB work space. Once Post-processing is made we get the edge detected pothole image. Figure 4.1 & Figure 4.2 shows the output images of Prewitt algorithm for various images. According to the subjective image assessment peakSNR of prewitt is 9.2306dB and that of canny is 6.8542dB. Therefore the peakSNR of prewitt proves better compared to canny operator (which is more predominant in edge detection) for pothole detection application.

Figure 4.1 Prewitt operator response over the Pothole Image1.

Figure 4.2 Prewitt operator response over the Pothole Image2

V. Conclusion

The pothole images and the plain road images were stored in the block ROM using the IP core of the Xilinx FPGA. These images were processed using the Prewitt edge detection algorithm implemented in Simulink of MATLAB and in verilog HDL. The VGA interfacing with the same FPGA kit was successfully done and was tested independently. The entire system was tested independently and integrated successfully. These pixel values are stored in text format file and used as input to the canny edge operator which is coded using Verilog.

The outcome result of the simulation of Verilog code is further saved in the text format file and applied to the post processing block of the MATLAB to get the edge extremities output. Display on the monitor is accomplished using VGA interfacing . An image of size 128×128 is first stored in block ROM on FPGA and then processing is performed using Prewitt edge detection operator and displayed on VGA monitor. The entire system is developed is simulated and synthesized using Spartan 3E FPGA board. In future, videos can be saved in the memory and video edge detection operation can be performed by camera interfacing considering real time images and thus such automated system may be the boon for mankind as it may save the precious life of mankind.

As the camera interfacing with FPGA was independently done for image capturing and processing the same cane be extended for a continuous video processing and testing in future.

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