Implementation and performance analysis of Video Edge Detection system on Multiprocessor Platform

Mandeep Kaur
Department of Electronics and Communication
Thapar University
Patiala, Punjab, India

Kulbir Singh
Department of Electronics and Communication
Thapar University
Patiala, Punjab, India

***Abstract*— This paper presents an agile development, implementation of Edge Detection on SMT8039 based Video And Imaging module. With the development of video processing techniques its algorithm becomes more complicated. High resolution and real time application cannot be implemented with single CPU or DSP. The system offers significant performance increase over current programmable DSP-based implementations. This paper shows that the considerable performance improvement using the FPGA solution results from the availability of high I/O resources and pipelined architecture. FPGA technology provides an alternative way to obtain high performance. Prototyping a design with FPGA offer some advantages such as relatively low cost, reduce time to market, flexibility. Another capability of FPGA is the amount of support of logic to implement complete systems/subsystems and provide reconfigurable logic for purpose of application specific based programming. DSP's to provide more and more power and design nearly any function in a large enough FPGA, this is not usually the easiest, cheapest approach. This paper designed and implemented an Edge detection method based on coordinated DSP-FPGA techniques. The whole processing task divided between DSP and FPGA. DSP is dedicated for data I/O functions. FPGA's task is to take input video from DSP to implement logic and after processing it gives back to DSP. The PSNR values of the all the edge detection techniques are compared. When the system is validated, it is observed that Laplacian of Gaussian method appears to be the most sensitive even in low levels of noise, while the Robert, Canny and Prewitt methods appear to be barely perturbed. However, Sobel performs best with median filter in the presence of Gaussian, Salt and Pepper, Speckle noise in video signal.**

Keywords-Multiprocessor platform; Edge detection; Performance evaluation; noise.

I. INTRODUCTION

Video processing has been used in many fields such as industry, military, medical image processing, surveillances recording etc. Video and imaging applications demand a range of processes to be performed in single applications. Edge detection is one of the basic characteristics of the image [1]. It is an important basis for the field of image analysis such as: the image segmentation, target area identification, extraction and other regional forms .It is widely used in image segmentation, image recognition, and texture analysis of them. Edge detection[2] technology must not only detect the image gray value of the non-continuity, but also to determine their exact location .Although you can use multiple DSP's to provide more and more power and design nearly any function in a large enough FPGA, this is not usually the easiest, cheapest approach[3]-[6]. The obvious result is to mix the two technologies benefits of co-processing. But DSP and FPGA designs are quite disparate disciplines, involving very different techniques, skills and tools [7][8]. But the differences in DSP and FPGA create obstacles to a fluid co-design process rather unpalatable to a specialist in one of the two fields and even more so to an expert of neither. Integrating the hardware [8]-[14] it also presents a significant amount of work that you could avoid if you stuck with just one technology.

II. EDGE DETECTION

Edge has two properties--the direction and the magnitude [1], [2]. Usually the change of the gray level along the edge is flat, but the pixels perpendicular to the edge change dramatically. According to the characteristics of intensity change, it can be divided into step-type and roof- type. In step type, both sides of the pixel in value have changed significantly, and roof type, it is located in the gray scale to reduce the rate of change from the turning point. This paper introduces edge detection for video [10]-[16] on DSP-FPGA system i.e. SMT8039. These algorithms are based on the detection of discontinuities in the values of the grey levels of the image. The most widely used techniques are the generation of **a** differential image by means of Sobel, Prewitt, Robert, Canny and LOG operator[17]-[21]. The characteristics of these operators, regularity and efficiency, make them adequate for its implementation in an application specific architecture. These operators [5] are 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 [10]-[13] by means of the comparison of the amplitude values to a predefined threshold level. These are based on the gradient operator. The first derivative of the digital image is based on various approximations to the 2-D gradient. The gradient of the image f(x, y) at location (x, y) is defined as the vector.

$$\Delta f = \begin{bmatrix} \partial f/\partial x \\ \partial f/\partial y \end{bmatrix} \qquad (1)$$

We know that gradient vector points in the direction of maximum rate of change of at coordinates(x,y). An important quantity in edge detection is magnitude of this vector. Δf= mag(Δf)=$[G_x^2+G_y^2]^{1/2}$ .The direction of the gradient vector also is an important quantity. Let α(x,y) represents the direction [1],[2] angle of the vector Δf at (x, y) then from vector analysis:

$$\alpha(x,y) = \tan^{-1}\left(\frac{Gy}{Gx}\right) \qquad (2)$$

Computational of the gradient of an image is based on obtaining the partial derivatives ∂f/∂x and ∂f/∂y at every pixel location. The 3X3 area mask in Fig. 1 for Sobel in Fig. 2 and Prewitt in Fig. 3 operations mask of 3X3, and for Robert operation 2X2 mask is shown in Fig. 4 are used to convolve with each pixel values of the image

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

Figure 1. 3x3 neighboring of pixels in an image

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Figure 2. Sobel matrix x and y directional

-1	-1	-1
0	0	0
1	1	1

-1	-1	-1
0	0	0
1	1	1

Figure 3.Prewitt matrix x and y directional

-1	0
0	1

0	-1
1	0

Figure 4.Robert matrix x and y directional

For Sobel equation is

$$\mathrm{Gx} = (\mathrm{Z7} + 2\mathrm{Z8} + \mathrm{Z9}) - (\mathrm{Z1} + 2\mathrm{Z2} + \mathrm{Z3})$$

$$Gy = (Z3 + 2\,Z6 + Z9) - Z1 + 2Z4 + Z7) \qquad (3)$$

For prewitt equation is

$$Gx = (Z7 + Z8 + Z9) - (Z1 + Z2 + Z3) \quad Gy = (Z3 + Z6 + Z9) - (Z1 + Z4 + Z7) \qquad (4)$$

And for Robert equation is

$$\mathrm{Gx} = (\mathrm{Z1} - \mathrm{Z4})$$

$$Gy = (Z2 - Z3\,) \qquad (5)$$

In this formulation, the difference between the first and third rows of the 3X3 image region approximates the derivative in x-direction and the difference between the third and first columns approximates the derivatives in the y-direction. However this implementation is not always desirable because of the computational burden required by Squares and Square root. The equation is much more attractive computationally, and it still preserves relative changes in gray levels. The laplacian is not used in original form because its magnitude produces double edges. The purpose of this operator is to provide image with zero crossing used to establish the location of edges.

III. System Architecture

System architecture includes:

1. CCD camera for PAL or NTSC standard video input.

2. TMS320DM642 DSP board is used as executing image processing algorithms [4].

3. Video processing board is shown as dashed frame in Fig. 6. FPGA is used as logic unit. Virtex 4 FPGA is connected to the DSP's EMIF[4][5]. This allows high speed transfers to be initiated at request. The Module features a single Philips Semiconductors SAA7109AE/108AE video decoder/encoder that accept most PAL and NTSC standards, and can output processed images in PAL/NTSC or VGA (1280x1024, or HDTV Y/Cb/Cr) The DM642 has 128 Mbytes of high speed SDRAM (Micron MT48LC64M32F2S5) available onboard for image processing and an 8Mbytes FLASH device is fitted to store programs and FPGA configuration information. The function SAA7109AE/108AE is to change analog video signals from CCD into digital signal and the image data with the format of YUV 4:2:2 are stored in SDRAM.

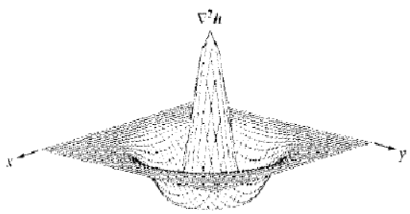
4. VGA display is used as displaying output Image.

IV. Design and Implementation of Edge Detection System on Software

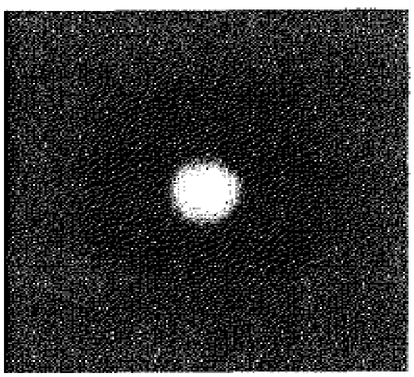
The software 3L Diamond for SMT339 provides a model describing multiprocessor system as a no. of independent tasks that communicate together over a channel[4][5]. Weather these tasks are executing on DSP or FPGA Diamond manages the interconnection and programming so that you can concentrate on the application In this system, different module (tasks) are created. These connections are logically defined for communication between different tasks for DSP and FPGA [14][15][21]. In DSP, a Task Dsp_pal which is written in c language, In DSP, frames information like no. of input frames, no. of output frame, video memory [1] for channel A, B video capture registers, FIFO registers are defined in the library are imported, there are 3 video ports: Vp1 is used for input the video from the camera, Vp2 is undefined and video port Vp0 is used for displaying video on VGA display. For RGB656 format this involves a single EDMA channel, so DMA transfer 64 bit data and for YCbCr, it contains 3 separate channels for initialization.

V. VIDEO EDGE DETECTION SYSTEM TESTS

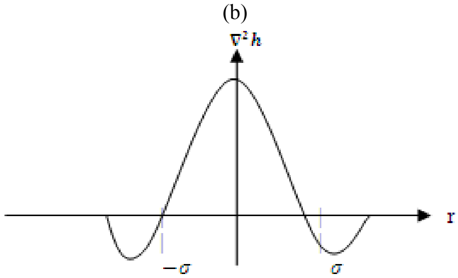
In this paper we take a frame of video and we perform different edge detection techniques on this frame. In this we added noise like Gaussian, salt and pepper, speckle[22]-[25]. In this paper, we estimate the effect of noise on different edge detection algorithms that which one is more sensitive to the noise, Original video frame is shown in Fig. 10. Fig. 11 shows effects of noise on different edge detection techniques at different PSNR values.



(a)



(b)



(c)

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

(d)

Figure 5.Laplacian of Gaussian) 3D- plot (a) Image black is negative, gray is zero and white is positive. (c) Cross section showing zero crossing (d) 5x5 mask of LOG.

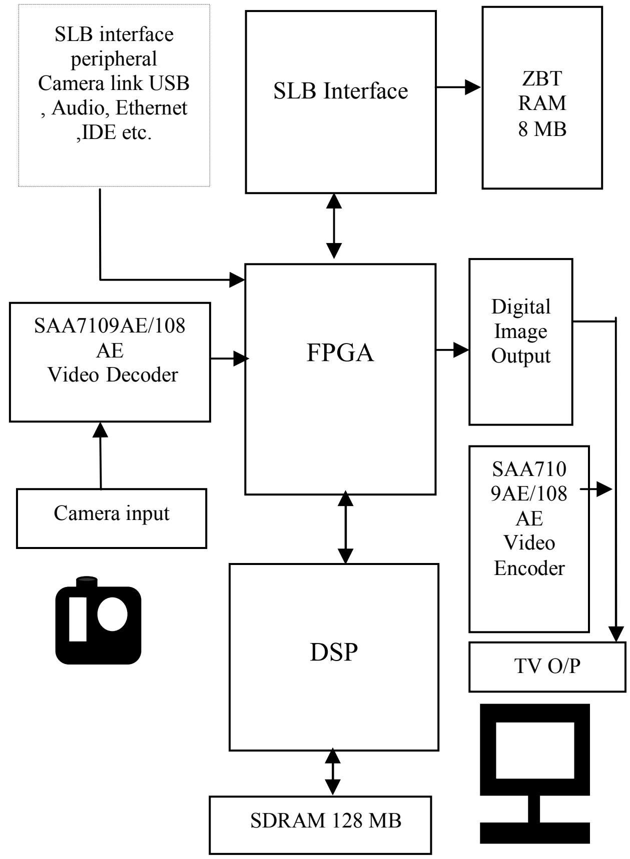


Figure 6. System Architecture

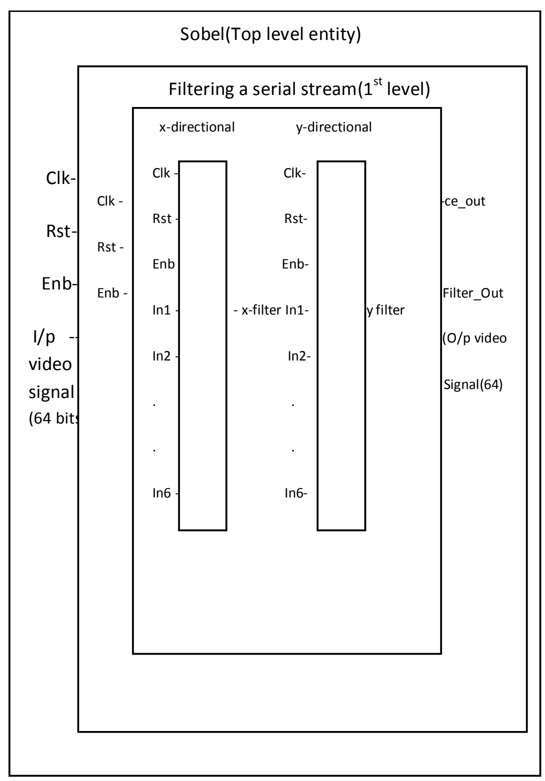


Figure 7.Entity for edge detection (Sobel, Prewitt)

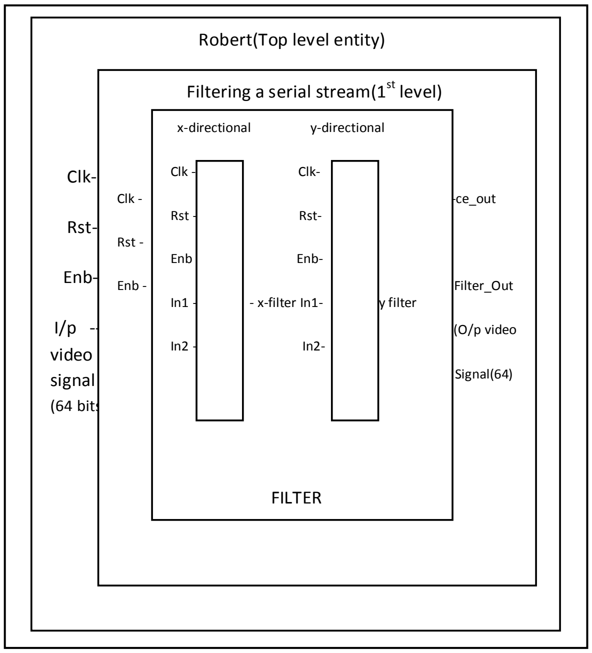


Figure 8.Entity for edge detection (Roberts)

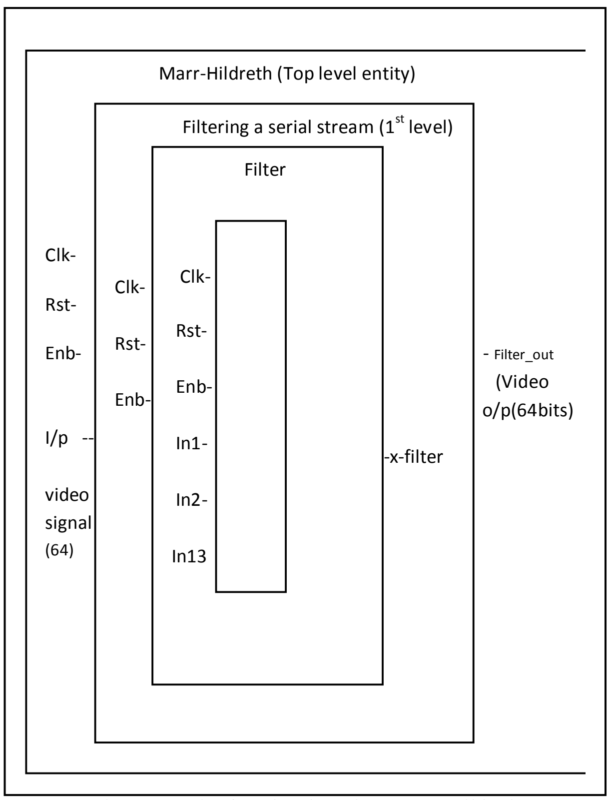
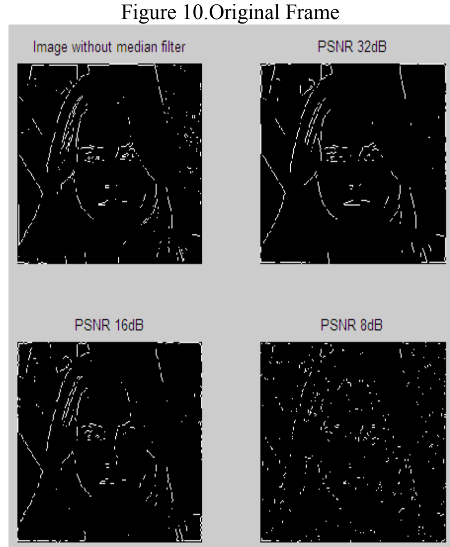
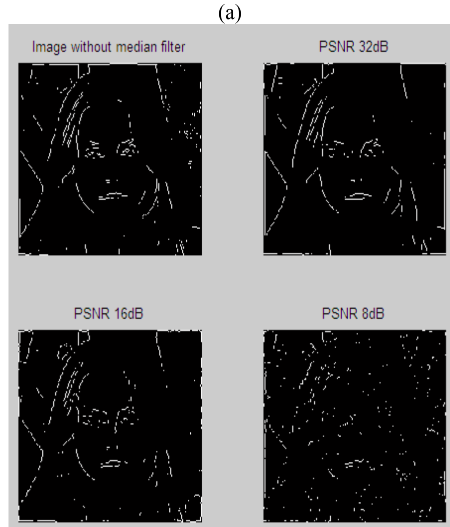


Figure 9.Entity for edge detection (Marr -Hildreth)s

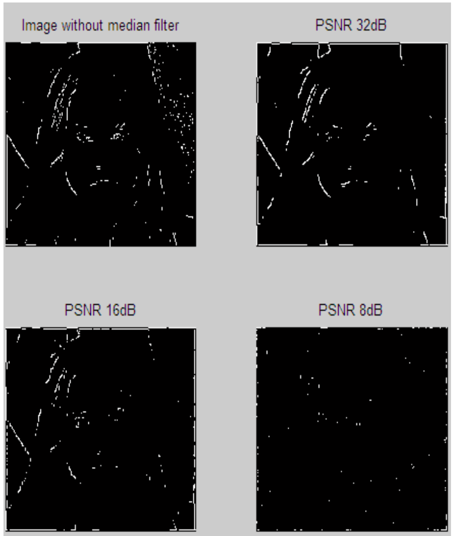
Figure 10.Original Frame



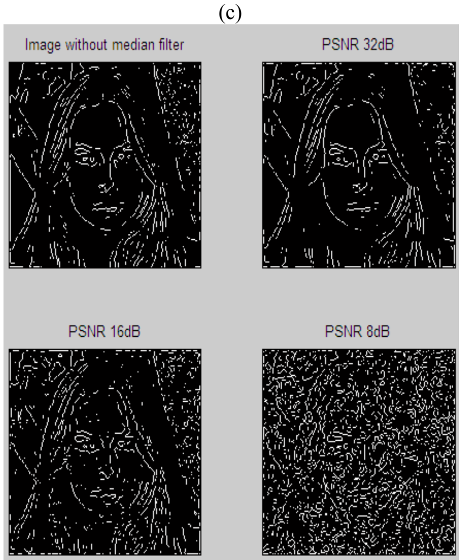
(a)



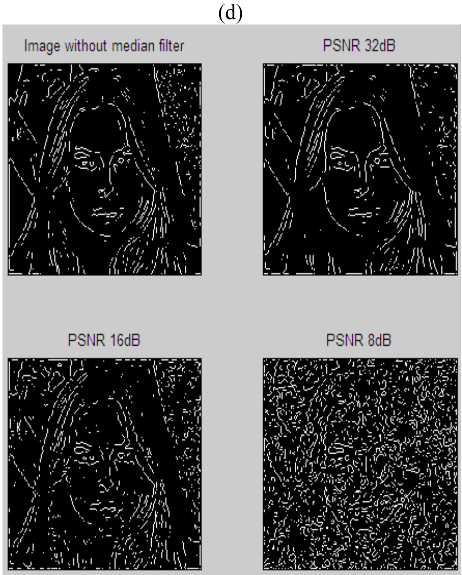
(b)



(c)



(d)



(e)

Figure 11. (a) Sobel operation at different PSNR (b) Prewitt operation at different PSNR (c) Roberts operation at different PSNR (d) Marr-Hildreth operation at different PSNR (e) Canny operation at different PSNR

TABLE I.

EFFECT OF GAUSSIAN NOISE ON DIFFERENT EDGE DETECTION TECHNIQUES				
PSNR of noisy image(dB)	***PSNR of noisy image after median filter(dB)***	***Edge Detection Technique (dB)***	***PSNR of edge detection before Median filter(dB)***	***PSNR Of edge detection after Median filter(dB)***
38.3437	24.4731	Sobel	3.1254	4.1513
		Prewitt	11.0582	12.058
		Robert	12.6772	11.0199
		Marr-Hildreth	10.7655	10.2409
		Canny	10.3832	11.2856
16.0414	21.4583	Sobel	7.1792	13.0138
		Prewitt	8.6966	13.1051
		Robert	15.1037	12.8259
		Marr-Hildreth	10.9128	9.88
		Canny	4.9631	11.2809
10.487	17.297	Sobel	0.0508	12.7839
		Prewitt	9.6073	13.2758
		Robert	15.5064	13.772
		Marr-Hildreth	10.7196	10.0412
		Canny	9.9918	11.1472
8.1645	14.7276	Sobel	-3.857	11.6824
		Prewitt	-3.5126	11.5007
		Robert	13.2864	11.2624
		Marr-Hildreth	10.404	10.2732
		Canny	10.2075	10.8719

PSNR in dB for Gaussian Noise

We also compare the PSNR values of the all the edge detection techniques which are listed above with different kinds of noise levels and noise type [21] [26] [27]. Out of five operators, Sobel edge detection method is found as the best in detecting the edges in noisy images. By applying median filter to the noisy image, noise is removed from the images and then all techniques are applied to filtered frame [28]. So the paper concludes that Sobel edge detector with the Median filter performs well in detecting the edges, when compared to other edge detector with median filter [28][23].

In Fig. 11a, shows Sobel operation, Fig. 11b shows Prewitt operation, Fig 11c shows Robert's operation and Fig. 11d shows LOG operation and Fig. 11e shows Canny. Fig 11a shows image with median filter original and second image at 32dB PSNR, 3rd at 16dB and last one at 8dB. Here PSNR is calculated by comparing the mean of the pixel values with the mean of the additive Gaussian noise [29][23]. The noise is multiplied by the proper scale so that it has a mean value of 0.016 for the 32 dB case. At this PSNR level, all methods return acceptable results. As the values of PSNR decreased, performance decreased [30]-[35].

TABLE II.

EFFECT OF SALT & PEPPER NOISE ON DIFFERENT EDGE DETECTION TECHNIQUES

PSNR of noisy image(dB)	*PSNR Of Noisy Image After median filter(dB)*	*Edge Detection Techniques (dB)*	*PSNR Of edge detection before Median filter (dB)*	*PSNR edge detection after Median filter (dB)*
16.139	21.5725	Sobel	1.921	4.2946
		Prewitt	6.6144	12.5597
		Robert	12.8492	11.0199
		Marr-Hildreth	10.0447	10.5141
		Canny	10.1012	11.963
12.7221	19.8018	Sobel	2.4532	12.5432
		Prewitt	2.9922	12.4228
		Robert	12.7041	12.9375
		Marr-Hildreth	10.0029	10.3087
		Canny	9.9916	10.8565
19.5703	23.1778	Sobel	7.9475	12.5191
		Prewitt	10.23	12.5832
		Robert	12.7041	12.285
		Marr-Hildreth	10.1879	10.6876
		Canny	10.2506	11.1916
13.4067	20.0276	Sobel	3.155	12.5415
		Prewitt	3.7613	12.464
		Robert	12.8773	12.8604
		Marr-Hildreth	9.9325	10.5383
		Canny	10.0141	10.9018

PSNR in dB for Salt and Pepper noise

TABLE III.

EFFECT OF SPECKLE NOISE ON DIFFERENT EDGE DETECTION TECHNIQUES

PSNR Of noisy image(dB)	*PSNR Of Noisy Image After Median Filter(dB)*	*Edge Detection Techniques (dB)*	*PSNR of edge detection before Median filter (dB)*	*PSNR edge detection after Median filter (dB)*
23.9577	23.417	Sobel	3.3957	4.332
		Prewitt	12.4686	12.6079
		Robert	14.3418	12.563
		Marr-Hildreth	10.3874	11.3048
		Canny	10.2656	10.78
21.0908	23.3807	Sobel	10.6997	13.1004
		Prewitt	12.7342	13.143
		Robert	15.2956	12.563
		Marr-Hildreth	10.3882	11.3595
		Canny	10.2664	10.834
15.02323	20.8912	Sobel	7.9304	13.7925
		Prewitt	12.7663	13.0254
		Robert	18.2607	13.2232
		Marr-Hildreth	10.3815	11.704
		Canny	10.2504	11.3389
18.2588	22.5847	Sobel	10.1194	13.438
		Prewitt	12.1019	13.8302
		Robert	16.5047	12.7849
		Marr-Hildreth	10.3638	11.4982
		Canny	10.2387	11.0434

PSNR in dB for Speckle Noise

TABLE IV
RESOURCES USED

BUFG	**DCM**	**RAM16**	**SLICES**
4 out of 32	***2 out of 12***	***1 out of 232***	***953 out of 25280***
12%	16%	1%	13%

TOTAL TIME FOR BUILDING THE APPLICATION:

Synthesis time: 70 second (1 min and 10 sec)
Translate: 19 second (0 min and 19 sec)
Map: 60 second (1 min and 10 sec)
Place and route: 61 second (1 min and 1 sec)
Generate bit stream: 32 second (0 min and 32 sec)

After the verification of this design in Xilinx FPGA development board, video edge detection system achieves the desired test results. Both filtering and edge detection perform well.

VI. CONCLUSION AND FUTURE WORK

This paper realizes a DSP-FPGA based video edge detection system and combines the respective strengths of FPGA's and DSP's can be starting with a scalable system. Supported by a comprehensive software environment, such complex hardware can become both adaptable and accessible Verification on SMT8039 development board and on VGA display indicates that the system can accurately detect the images edge and satisfy requirements of the real-time video image edge detection. Finally it achieves the desired experimental results. Out of five operators, Sobel edge detection method is found to be the best in detecting the edges in noisy images. The Laplacian of Gaussian method appears to be the most sensitive to even low levels of noise, while the other methods appear to be barely perturbed. In fact, even though the other methods appear to be returning nearly perfect results.

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AUTHORS PROFILE

Mandeep Kaur received the BTech. degree, in Electronics and Communication Engineering from Shaheed Bhagat Singh College of Engineering and Technology, Firozepur in 2008. She is currently pursuing the M.E degree in Electronics and Communication at Thapar University, Patiala.Her research interests include Video Compression and Evaluation of algorithms.

Dr. Kulbir Singh was born in Batala (Pb) India. He received his BTech degree in 1997 from PTU, Jalandhar. He obtained his ME and PhD degree from Thapar Institute of Engineering and Technology, Patiala in 2000 and 2006 respectively. He worked as lecturer from 2000 to 2007 in Electronics and Communication Engineering Department, Thapar University, Patiala. Presently he is working as Assistant Professor in Thapar University, Patiala since July 2006. He has published about 60 research articles in refereed international journals, international conference and national conference. He is life time member of IETE and ISTE. His research interest include Digital Signal Processing, Image Processing, Fractional Fourier Transform and Communication systems.