Implementation of Running Average Background Subtraction Algorithm in FPGA for Image Processing Applications

S.Susrutha Babu
Assistant Professor
Department of ECE
K L University
Vaddeswaram, Guntur

S.Suparshya Babu
Assistant Professor
Department of ECE
K L University
Vaddeswaram, Guntur

Dr.Habibulla Khan
Professor & Head
Department of ECE
K L University
Vaddeswaram, Guntur

M.Kalpana chowdary
M.Tech VLSI Student
Department of ECE
K L University
Vaddeswaram, Guntur

ABSTRACT

In this paper a new background subtraction algorithm was developed to detect moving objects from a stable system in which visual surveillance plays a major role. Initially it was implemented in MATLAB. Among all existing algorithms running average algorithm was choosen because of low computational complexity which is the major parameter of time in VLSI. The concept of the background subtraction is to subtract the current image with respect to the reference image and compare it with to the certain threshold values. We propose a new real time background subtraction algorithm which was implemented with verilog hdl in order to detect moving objects accurately. Our method involves three important modules background modelling; adaptive threshold estimation and finally fore ground extraction. Compared to all existing algorithms our method having low power consumption and low resource utilization. Here we have written the core processor Microblaze is designed in VHDL (VHSIC hardware description language), implemented using XILINX ISE 8.1 Design suite the algorithm is written in system C Language and tested in SPARTAN-3 FPGA kit by interfacing a test circuit with the PC using the RS232 cable. Area and the speed of the algorithm are also evaluated.

KEYWORDS

Background Subtraction, Micro blaze, Object Detection, UART, VHDL.

1. INTRODUCTION

Extracting moving objects from image sequences is fundamental problems in computer vision systems that are used in a variety of applications, such as video surveillance, human tracking, motion analysis and image synthesis .To detect the target, we use methods such as background subtraction [1], inter –frame difference and optical flow. Frame difference method is highly adaptive to dynamic environments, but generally does a poor job of extracting the complete shapes of certain types of moving objects. Optical flow [6] is an approximation of the local image motion and specifies how much each image pixel moves between adjacent images. Optical flow is a very complex algorithm (it is necessary to store more than one image), requiring high memory resources and also it is hard to apply in real-time due to its high computational cost. In most of the cases, a stationary camera is used, which means that background subtraction techniques can be a power full tool for object detection. The simplest implementation of background subtraction is to evaluate the difference between a background image and current image in a pixel wise manner, and then thresholding the difference value to determine the pixels that belongs to moving objects. Common background subtraction methods include Running Average (RA) , Gaussian mixture model GMM) and nonparametric kernel methods[2]. Although GMM and nonparametric methods are stable algorithms their complexity makes it possible to be implemented by hardware approach. RA is also a stable algorithm, but its signal processing is more tractable for hardware implementation because of single modality in statistical modeling.

2. THE REAL TIME BACKGROUND SUBTRACTION DESIGN

This section first reviews the formulation of the Running Average algorithm. The Real time background subtraction improving the Running average algorithm by removing division operation is then described. Dataflow of the Real time background subtraction is also analyzed.

Review of Running Average Algorithm : The RA algorithm includes two steps: differencing step and background modeling step. The differencing step extracts motion pixels by computing the difference between current frame and background model. The background model is statistically built with single modality assumption.

The differencing step can be formulated as follows:

$$M_{t+1}(x,y) = |\, P_{t+1}(x,y) - B_t(x,y) \,| \qquad (1)$$

where $P_{t+1}(x,y)$ is the pixel value of current frame at time t+1, $B_t(x,y)$ is the background model at time t, and $M_{t+1}(x,y)$ is the subtraction result. The background model of each pixel is assumed to be a single Gaussian, and its parameters can be recursively updated by new frame, which can improve computational efficiency and reduce memory resource allocation. The recursive form of expected value of the single Gaussian, $B_t(x,y)$, is described as follows:

$$B_t(x,y) = \frac{k}{k+1} B_{t-1}(x,y) + \frac{1}{k+1} P_t(x,y) \qquad (2)$$

where $B_t(x,y)$ is the established background image at time t, and k is the learning parameter controlling learning speed of background. The difference image M_{t+1} is then thresholded into T_{t+1} by an adaptive threshold obtained by recursively updating the variance of the Gaussian model.

$$T_{t+1}(x,y) = \begin{cases} 1, & if \;\; M_{t+1}(x,y) < \lambda\sigma_t^2\,(x,y), \\ 0, & otherwise \end{cases} \qquad (3)$$

$$\sigma_t^2\,(x,y) = \frac{k}{k+1}\sigma_{t-1}^2\,(x,y) + \frac{1}{k+1} M_t^2\,(x,y) \qquad (4)$$

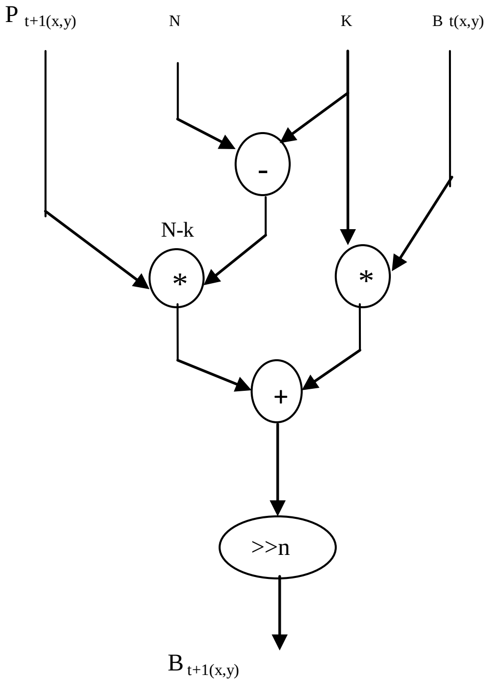


Figure 1. Data flow diagram of the background modeling in Eq. (5)

where standard deviation $\sigma_t(x,y)$ is applied to the adaptive threshold and recursively updated by current frame. The parameter _ determines the desired precision of thresholding. The above formulation for background subtraction and updating includes five multiplications, two divisions, and one radical expression operation. The divisions in Eqs. (2) and (4) require lots of logic circuit resources and can slow down computational performance. By applying integer arithmetic to replace division operation with bit shifting, we can greatly improve the hardware design of the RA algorithm.

In addition, the variance σ_t^2 obtained in Eq. (4) has to be square-rooted into standard deviation σ_t for the thresholding in Eq. (3). The implicit radical expression needs to be eliminated. As a result, reformulation is necessary in order to shorten computational time as well as reduce resource utilization.

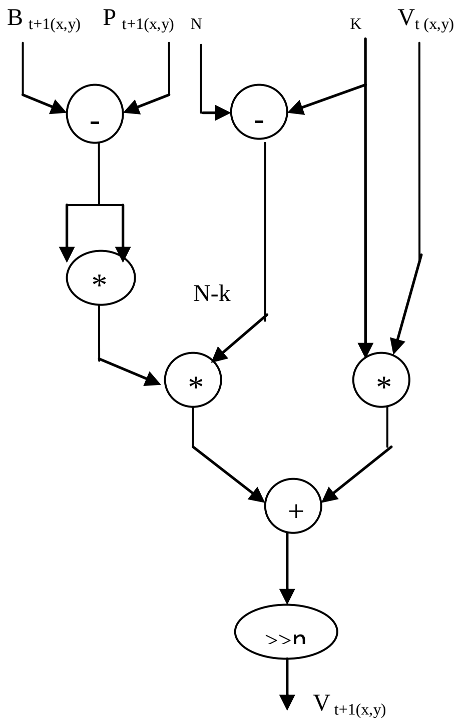


Figure 2. Data flow diagram of adaptive threshold determination in Eq. (6)

B. The RTBS Algorithm

To apply shift circuit instead of division we have to modify the denominators of Eqs. (2) and (4). And we replace the σ_t^2 with V_t and substitute the σ_t in Eq. (3) with V_t , where both sides of the condition have to be squared. The three new equations are given below:

$$B_t(x,y) = \frac{k}{N} B_{t-1}(x,y) + \frac{(N-k)}{N} P_t\,(x,y),\; 0 < k < N, \qquad (5)$$

$$V_t(x,y) = \frac{k}{N} V_{t-1}(x,y) + \frac{(N-k)}{N}\, M_t^2\,(x,y),\; 0 < k < N, \qquad (6)$$

$$T_{t+1}(x,y) = \begin{cases} 1, & if \;\; M_{t+1}^2(x,y) < \lambda^2\, V_t(x,y), \\ 0, & otherwise \end{cases} \qquad (7)$$

where *N* is the m power of 2, i.e., *N*= 2^m . We replace the $\frac{k}{k+1}$ of RA with $\frac{k}{N}$, and $\frac{1}{k+1}$ with $\frac{N-k}{N}$.

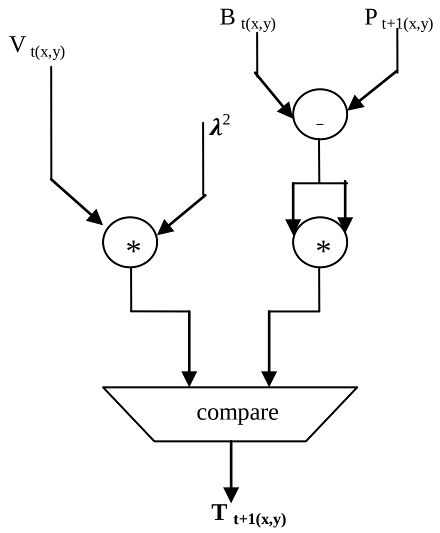


Figure 3. Data flow diagram of the foreground extraction in Eq. (7)

As a result, we apply shift circuit to replacing division operations. Mathematically the reformulation produces residue between RA and RTBS on background updating. But we can demonstrate that practically the residue vanished as *t* increases. Before using Verilog for hardware design, we first analyze Eq. (5) with more details to identify the data flow of background updating. The data flow is shown in Fig. 1. Data flow of Eq. (6) to find adaptive threshold is shown as Fig. 2. Eq. (7) performs a new adaptive thresholding mechanism to find objects. Its dataflow diagram is shown in Fig. 3.

3. FLOW DIAGRAM FOR OBJECT DETECTION IMPLEMENTED IN FPGA

In the first step we consider the video and convert it into frames, from that frames we can select any of two images for that two images we create a header file .And then we can write an algorithm for back ground subtraction in the XPS tool by using system 'C' language. In the XPS we are giving two inputs of headerfile.h and source file.c. XPS is a tool used to link a program to hardware like FPGA. After downloading the bit stream open the visual basics application and click run button on the command window of XPS .Finally with the help of UART port and RS232 cable we made a communication between hard ware and our PC and we can see the output image in the PC with the help of visual bascis tool.

The Xilinx Platform Studio (XPS) is the development environment used for designing the hardware portion of our embedded processor system and Xilinx Embedded Development Kit (EDK) is an integrated software tool suite for developing embedded systems with Xilinx MicroBlaze and PowerPC CPUs. The Microprocessor Hardware Specification (MHS) file defines the hardware component. The MHS file serves as an input to the Platform Generator (Platgen) tool. The Microprocessor Software Specification (MSS) is used as an input file to the Library Generator (Libgen). The MSS file contains directives for customizing operating systems (OS), libraries, and drivers. The User Constraints File (UCF) specifies timing and placement constraints for the FPGA Design. The features of the visual basics are Improved performance ,Visual data access with the data control so that it is possible to create data browsing application without writing code.

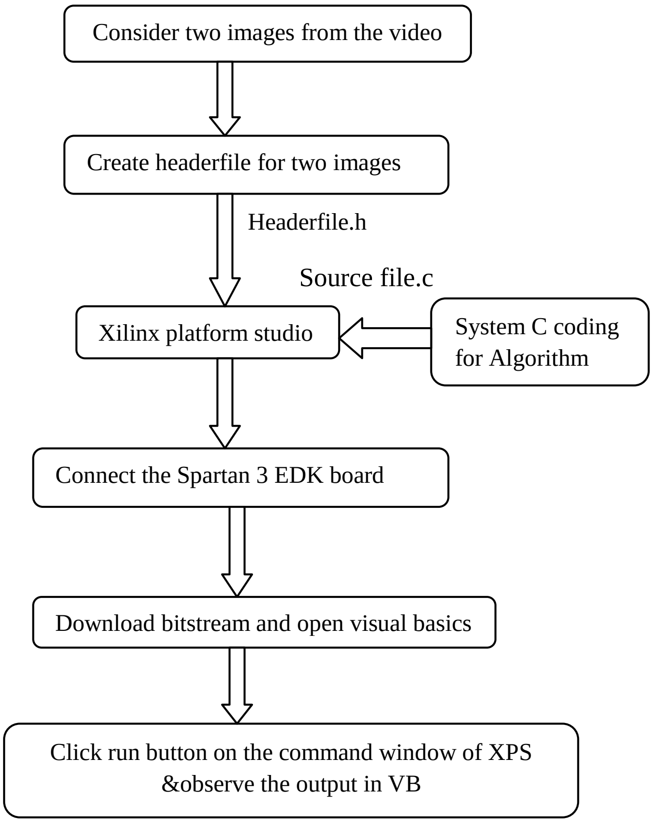

Consider two images from the video
Create headerfile for two images
Headerfile.h
Source file.c
Xilinx platform studio
System C coding for Algorithm
Connect the Spartan 3 EDK board
Download bitstream and open visual basics
Click run button on the command window of XPS &observe the output in VB

Fig 4: Flow diagram for FPGA implementation of object detection

4. EXPERIMENTAL RESULTS

4.1 Tracking implemented in MATLAB GUI

MATLAB implements GUIs as figure windows containing various styles of uicontrol objects.GUI includes laying out the components, programming them to do specific things in response to user actions.GUIDE also generates an M-file that contains code to handle the initialization and launching of the GUI.

In this tracking first consider a small video and then separated into frames. After frame separation the object was detected, to remove the noise in the images we are using filters. The median filter[7] is normally used to reduce noise in an image. The median is a more robust average than the mean and so a single very unrepresentative pixel in a neighborhood will not affect the median value significantly. Since the median value must actually be the value of one of the pixels in the neighborhood, the median filter does not create new unrealistic pixel values. Thus the median filter is much better at preserving sharp edges than the mean filter.

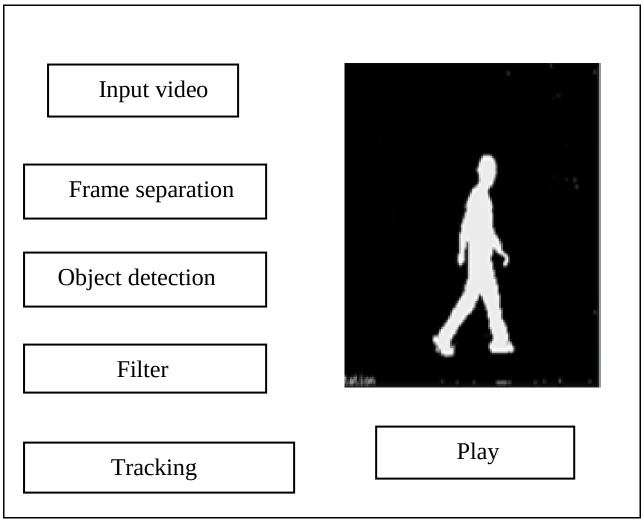
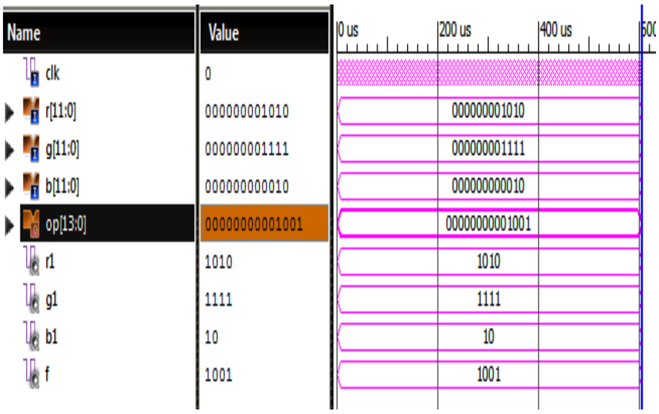


Fig 5: Tracking result implemented in GUI

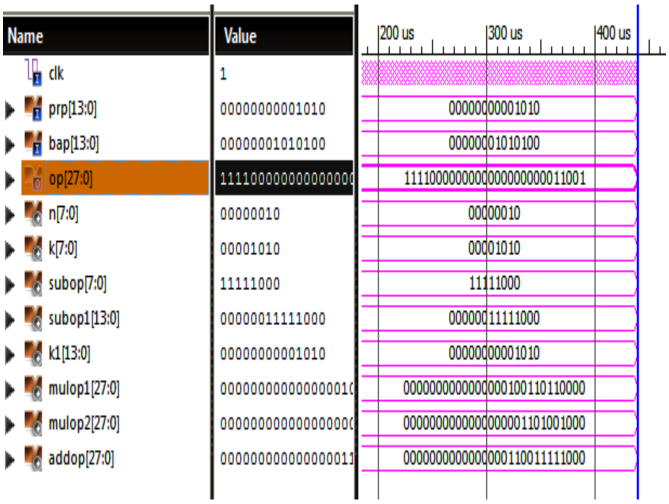
4.2 object detection implemented in VHDL

The theoretical calculations were implemented by using running average algorithm to perform both differencing step and background modeling step after background modeling calculate the threshold value and compare the subtraction result with threshold value finally motion detected pixels are observed. For that the code was written in VHDL language and verify the output waveforms by using model sim tool.



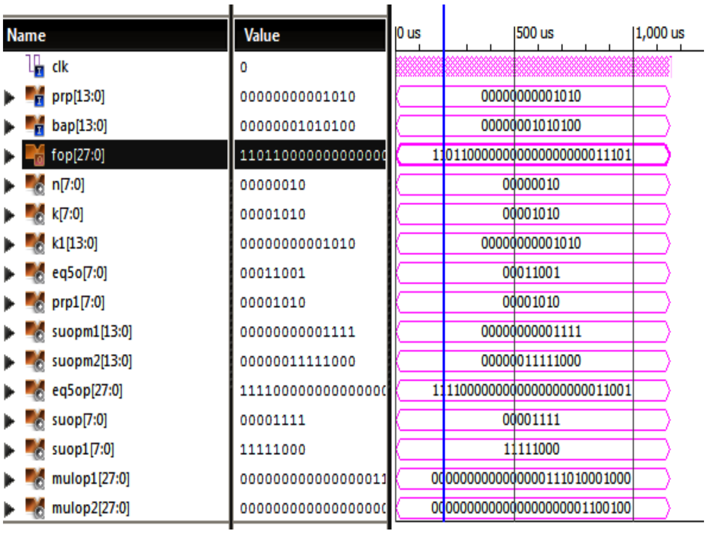
Name	Value	0 us 200 us 400 us 50(
clk	0	
r[11:0]	000000001010	000000001010
g[11:0]	000000001111	000000001111
b[11:0]	000000000010	000000000010
op[13:0]	00000000001001	00000000001001
r1	1010	1010
g1	1111	1111
b1	10	10
f	1001	1001

Fig 6: Calculation of intensity values



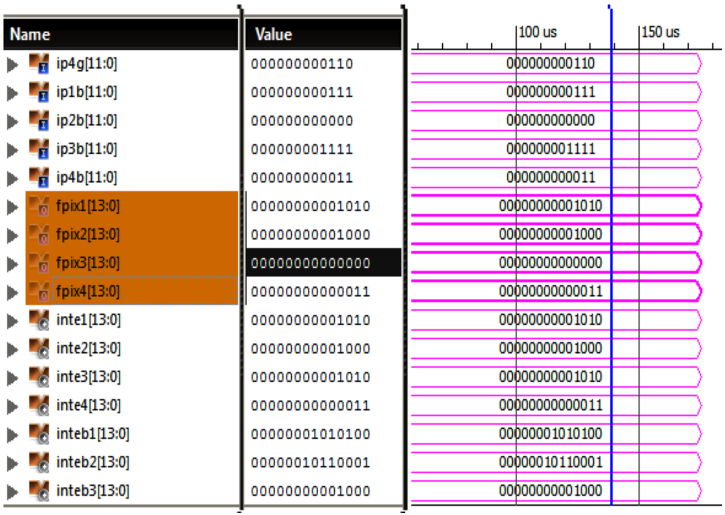
Name	Value	200 us 300 us 400 us
clk	1	
prp[13:0]	00000000001010	00000000001010
bap[13:0]	00000001010100	00000001010100
op[27:0]	111100000000000000	1111000000000000000000011001
n[7:0]	00000010	00000010
k[7:0]	00001010	00001010
subop[7:0]	11111000	11111000
subop1[13:0]	00000011111000	00000011111000
k1[13:0]	00000000001010	00000000001010
mulop1[27:0]	0000000000000000010	0000000000000000100110110000
mulop2[27:0]	0000000000000000000	0000000000000000001101001000
addop[27:0]	0000000000000000011	0000000000000000110011111000

Fig 7: background modeling



Name	Value	0 us 500 us 1,000 us
clk	0	
prp[13:0]	00000000001010	00000000001010
bap[13:0]	00000001010100	00000001010100
fop[27:0]	110110000000000000	1101100000000000000000011101
n[7:0]	00000010	00000010
k[7:0]	00001010	00001010
k1[13:0]	00000000001010	00000000001010
eq5o[7:0]	00011001	00011001
prp1[7:0]	00001010	00001010
suopm1[13:0]	00000000001111	00000000001111
suopm2[13:0]	00000011111000	00000011111000
eq5op[27:0]	111100000000000000	1111000000000000000000011001
suop[7:0]	00001111	00001111
suop1[7:0]	11111000	11111000
mulop1[27:0]	0000000000000000011	0000000000000000111010001000
mulop2[27:0]	0000000000000000000	0000000000000000000001100100

Fig 8: Adaptive threshold determination



Name	Value	100 us 150 us
ip4g[11:0]	000000000110	000000000110
ip1b[11:0]	000000000111	000000000111
ip2b[11:0]	000000000000	000000000000
ip3b[11:0]	000000001111	000000001111
ip4b[11:0]	000000000011	000000000011
fpix1[13:0]	00000000001010	00000000001010
fpix2[13:0]	00000000001000	00000000001000
fpix3[13:0]	00000000000000	00000000000000
fpix4[13:0]	00000000000011	00000000000011
inte1[13:0]	00000000001010	00000000001010
inte2[13:0]	00000000001000	00000000001000
inte3[13:0]	00000000001010	00000000001010
inte4[13:0]	00000000000011	00000000000011
inteb1[13:0]	00000001010100	00000001010100
inteb2[13:0]	00000010110001	00000010110001
inteb3[13:0]	00000000001000	00000000001000

Fig 9: Final motion detected pixel values

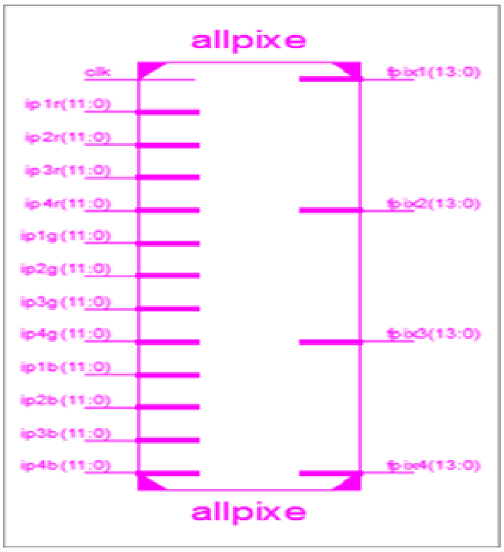


Fig 10: RTL Schematic of Top module

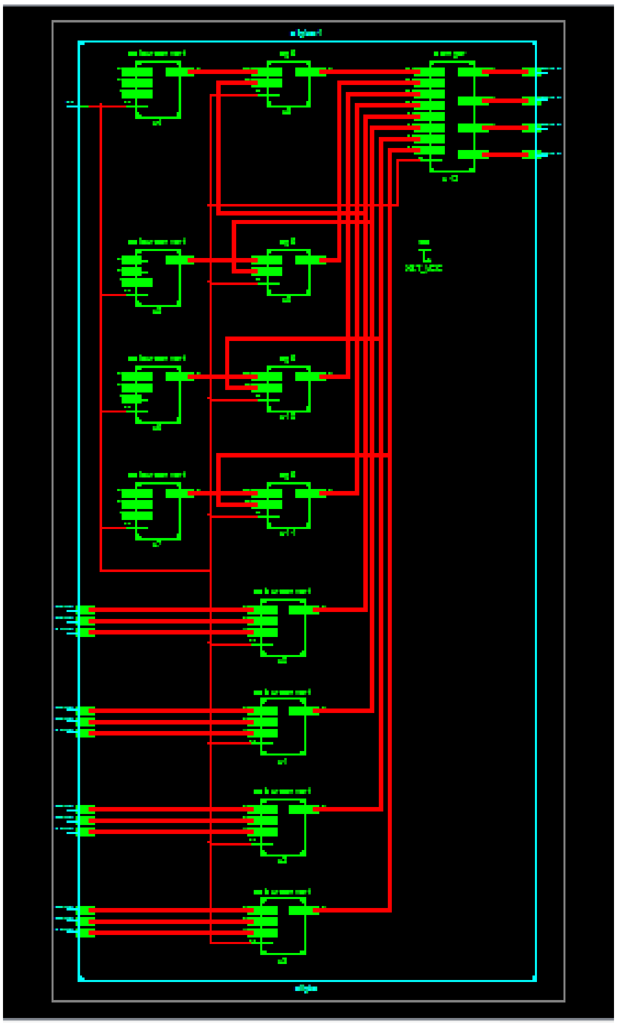


Fig 11: schematic of all individual modules

Device utilization summary			
Logic Utilization	Used	Available	Utilization
Number of Slices	409	4656	8%
Number of Slice Flip-flops	269	9312	5%
Number of 4 input LUTS	269	9312	86%
Number of bonded IOBS	201	2312	86%
Number of MULT 18*18SIOs	16	20	80%
Number of GCLK's	1	24	4%

Table 1: Synthesis report of object detection implemented in Xilinx

4.2 Object Detection Implemented in Hardware

The visual basics window appears in this manner in the right side the pixel values are moved one by one and after completion of all the pixel values the image was displayed on the right side of the window .

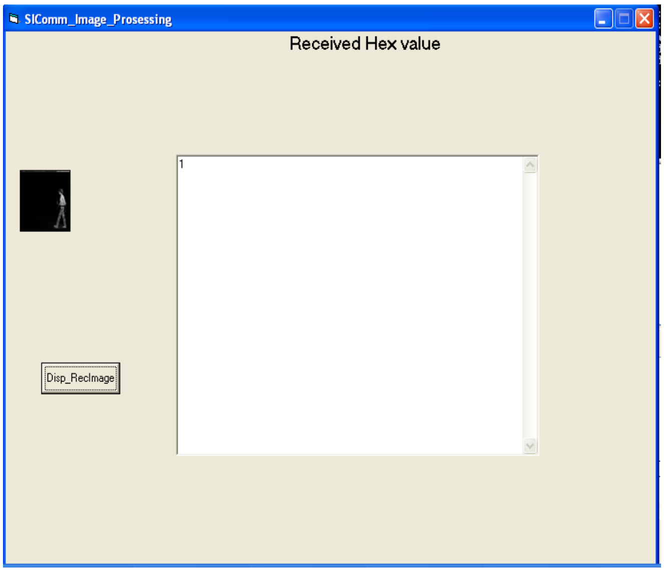
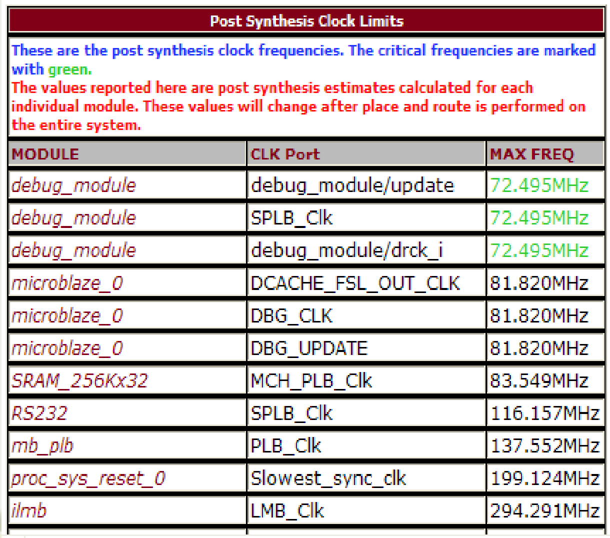


Fig 12: object detection output using visual basic



Post Synthesis Clock Limits

These are the post synthesis clock frequencies. The critical frequencies are marked with green.

The values reported here are post synthesis estimates calculated for each individual module. These values will change after place and route is performed on the entire system.

MODULE	CLK Port	MAX FREQ
debug_module	debug_module/update	72.495MHz
debug_module	SPLB_Clk	72.495MHz
debug_module	debug_module/drck_i	72.495MHz
microblaze_0	DCACHE_FSL_OUT_CLK	81.820MHz
microblaze_0	DBG_CLK	81.820MHz
microblaze_0	DBG_UPDATE	81.820MHz
SRAM_256Kx32	MCH_PLB_Clk	83.549MHz
RS232	SPLB_Clk	116.157MHz
mb_plb	PLB_Clk	137.552MHz
proc_sys_reset_0	Slowest_sync_clk	199.124MHz
ilmb	LMB_Clk	294.291MHz

Table 2:Post synthesis report of the Algorithm is implemented in Micro blaze Processor

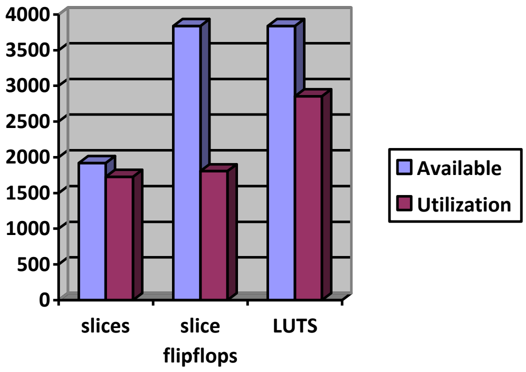


Fig 13: Area utilization

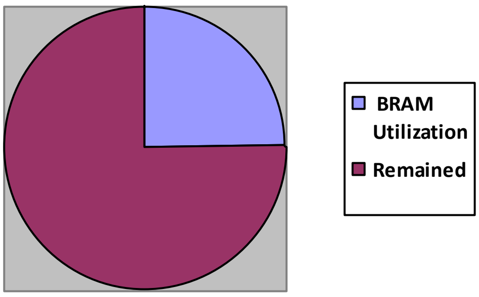


Fig 14: Memory Utilization

Logic Utilization	Used	Available	Utilization
Number of slices	1727	1920	89%
Number of slice Flip Flops	1805	3840	47%
Number of 4 input LUTS	2855	3849	74%
Number of Bonded IOBS	62	97	63%
Number of DCM'S	1	4	25%
Number of BSCANs	1	1	100%
Number of BUFGMUXs	2	8	25%
Number of BRAMS	3	12	25%

Table 3 : Device Utilization Summary in EDK

5. APPLICATIONS

1.Automated video surveillance: In these applications computer vision system is designed to monitor the movements in an area, identify the moving objects and report any doubtful situation. The system needs to discriminate between natural entities and human, which require a good object tracking system.

2. Robot vision: In robot navigation, the steering system needs to identify different obstacles in the path to avoid collision. If the obstacles themselves are other moving objects then it calls for a real-time object tracking system.

3. Traffic monitoring: Traffic is continuously monitored using cameras. Any vehicle that breaks the traffic rules or is involved in other illegal act can be tracked down easily if the surveillance system is supported by an object tracking system.

4. Animation: Object tracking algorithm can also be extended for animation.

5. Magnetic Resonance Imaging (MRI): Doctors can get highly refined images of the body's interior without surgery. MRI is particular useful for imaging the brain and spine, as well as the soft tissues of joints and the interior of bones.

6.CONCLUSION

In this work a moving object detection based on running average algorithm was developed with a verilog HDL and also implemented on hardware. And the high cost function background modeling, is reformulated by eliminating division operations that can both reduce resource utilization and improve performance compared to all existing algorithms this can help in lowering execution times for high-resolution sequences.

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