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FPGA IMPLEMENTATION OF OBJECT DETECTION IN BACKGROUND MODELING USING GAUSSIAN MIXTURE MODEL

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Abstract – Demand for implementation of image processing algorithm on FPGA is exponentially increases in the present world. Many research works is carried for image processing applications and implementation on FPGA. Nowadays identification, classification, and recognition of an object in the highly sophisticated regions are big challenge. Tracking intended object in the congestion region is very difficult. CCTV is used to detect and track the object in the traffic regions. Sometimes it gives false alarm by capturing shadows due to change in the intensity levels in the dynamic background. In this paper an efficient background circuit is developed to detect the object in the dynamic/static background to avoid false alarm. The real time captured image is processed by the proposed background circuit, and it is implemented on FPGA. It has been observed that the result obtained from this proposed work is good in terms of processing time and area utilization.

Keywords:- Gaussian mixture model(GMM),field programmable gate array (FPGA), background(Bg), image processing(IP), closed circuit television (CCTV).

1. INTRODUCTION

Now a days smart and intellectual real time surveillance embedded system is more demanded, due to high demand for security. These real time system operates on static/dynamic object detection/identification and tracking of the detected object in a given real time sequence. Now days, it is very difficult to provide real time security to the end users. Usually object tracing is done with the help of intensity of visible light image sensor (gray values). once the sequence is available, then digital algorithm is applied on the target to extract various parameters such as mean, standard deviation, skewness and kurtosis factors in the given real time video stream. Other Parameters also like position, velocity of the moving object (which helps in increase contrast of an image).

In this paper, we are designed and developed new improved version of real time security system module, which will reduces the false alerts and increases the quality of image for motion detection application. In this method we can avoid the false alert which is triggered to capture the scene. This new design will increase the memory utilization and also it reduces the power consumption. The quality of the image captured is also increased irrespective of the object motion with the help of Feature Extraction and ANN Model.

The massive demand for digital image segmentation in a dynamic background with high speed moving object in the foreground has thrown a lot of challenge for the designers. The fast background modeling for real time surveillance system is required to track the moving objects in an outdoor environment. The system is operated on grayscale images captured by infrared camera [1]. This system detects the foreground object in a dynamic background. Various probabilistic models are designed to track the region of interest in outdoor application and facing difficulties to use the motion models in classifying and tracking objects when detailed information of the objects' appearance is not available [2]. This system approach is very low false detection rate by segmenting the moving object. This system also uses shadow detection algorithm to solve the outdoor environmental problems. Lane modeling is presented in this work, initially traffic density and vehicle congestion is identified. Later vehicle detection and tracking is done with the help of multiple initial fames [3]. To remove the distorted pixels and smoothening of the resultant, kalman filter is utilized. The designed algorithm with kalman filter is tested efficiently over sequence of frames helps to solve the difficulties faced to track the moving objects. The improved version of an algorithm on frame difference is used with the help of canny detector to detect the edges of successive frames to get the resultant image [4][5]. Later segmentation is carried out by dividing resultant image into several sub blocks of sub images and then decides whether the sub images are moving by comparing the number of non zero pixel values with the threshold pixel values. Resultant of this process will be the identification /detection of moving object. Recognition of an object after finding the motion object is done with the help of frame difference algorithm and features of the moving object are extracted from the region of interest. Later vector standardization is done for extracted feature parameters, and then wavelet neural network along with genetic algorithm is used for pattern recognition [6][7]. A new approach, while detecting the moving object in the foreground should not consider the changing illumination in the background estimation [9]. This approach assumes static camera with static focal length. Statistical models are used to overcome the problems related to shadow boarders and the adaptation in a real time application, when the background scene is covered by foreground scene. Later, modeling of an each pixel is performed as a mixture of natural distribution to update Gaussian parameters in the exiting model.

Finally the adaptive mixture model is then evaluated to determine efficient background image [11]. Every pixel is classified based on their pixel values with Gaussian nature are considered to be part of background model. The resultant images are stable, dynamic outdoor tracker.

In this paper, there are two major areas we find difficulties, one is coupling of data from one process to other for processing. The challenge is that the number of bits required to represent the real time input image is too high and processing time is also high. It may cause delay, due to delay there may be chance of system failure. Other challenge is to identify/detection of motion object in the complex dynamic background. Many experiments/analysis are carried out related to our work in different domain. Considering the advantages and disadvantages of the previous work which are related to my work, an efficient algorithm is proposed in this paper to detect/identify the moving object in the dynamic/static background with high efficiency by reducing the false triggering of the system.

The utilization of Gaussian Mixture Model (GMM) is the biggest advantage because it is suitable to work with multimodal background based on stastical model.

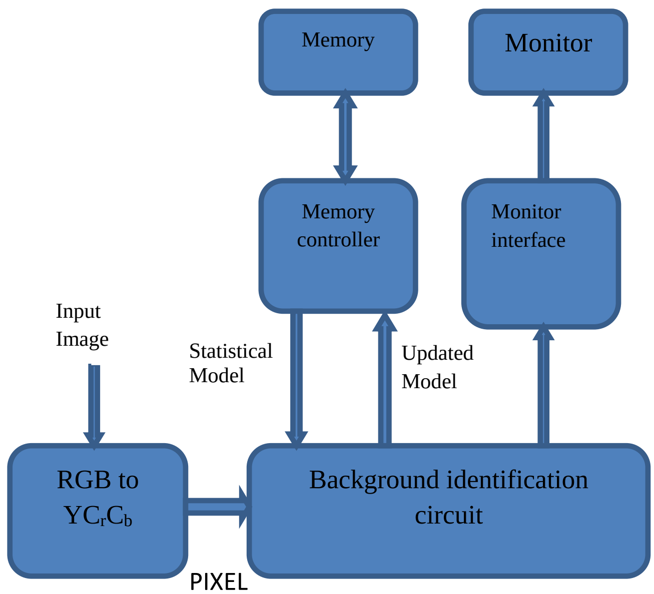

Figure 1. Block diagram for proposed GMM

The proposed main block diagram is as shown in the figure 1. The above diagram is categorize into three clusters/group, 1) the real time input image/video acquisition and interface. 2) Background identification/detection module, this module is used to track the moving object. 3) This block is used to interface the display units to project the detected object. This paper is organized by the following sections, Section 2 explains the generation of 3x3 memories blocks and color conversion. The implementation of background identification/detection is explained in the section 3. Proposed algorithm is explained in the section 4 with the help of flow chart. Section 5 explains the implementation of ANN module for fine tuning of the resultant image. Design simulation, synthesis results and comparison results are explained in the section 6. Section 7 includes conclusion and future work. The design improves the performance and quality of the image and efficient work towards the reduction of false triggering. Proposed Design is capable of performing an operation of moving object detection for the standard video in dynamic environment conditions which helps to reduce the false trigger alert.

2. MEMORY BLOCK GENERATION UNIT

Initially, the real-time image is captured for which our design is implemented. The proposed design is implemented on matlab and Xilinx. The proposed design is coded in matlab for standard conversion of data matrix in 1D. Here the complete image is converted into 256 x 256 image. This is in the form of gray scale image. It means the entire image is varied in the form of white and black color with different range of intensity values. Where, each pixel assigns a value of corresponding intensity value.

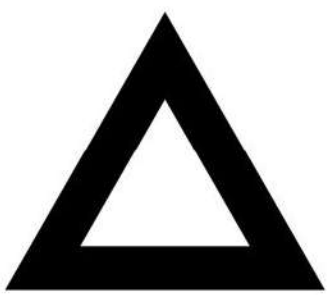

Figure 2: input image

Above figure 2 is used as an input for design. If the image is RGB then image is converted into chromatic image with a size of 256 x 256. With the help of MATLAB, text document is created which contains hexadecimal values of each pixel with the help Xilinx, again new file is created, which contains the pixel values of overlapped resultant image. The resultant image is also 256 x 256. There may be chance of high impedance values also created and these values are removed of before generating the resultant overlapped image when executed in supported with the matlab. The resultant image is as shown in fig 3.

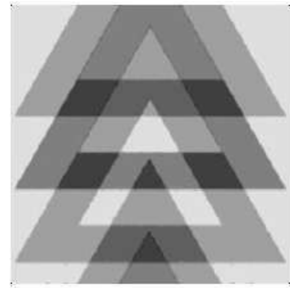

Figure 3: Output image

The main consideration has been taken initially, for a generation of 3 x 3 memory element image block for further processing of an image. The memory block has 776 locations were each location has capacity to store 8 bit resolution pixel values. Raw data of an 8 bit input image which is represented in serial format stored in the memory element. Below block diagram shows the generation of 3 x 3 blocks.

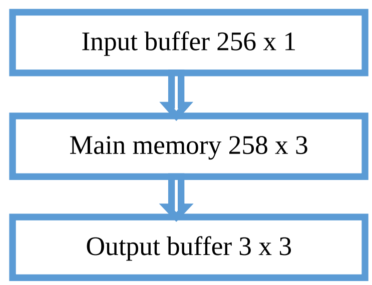

Figure 4: Basic block diagram of 3X3 block generation module.

The above figure 4 represents the basic block diagram of 3X3 block generation module. The design is implemented with the minimal memory.

3. BACKGROUND IDENTIFICATION / DETECTION CIRCUIT

The background detection/identification module plays superior role in the proposed design. Figure 5 block diagram shows the conceptual view of background identification/detection. The 8 bit real time image is captured by camera and its interface provides the pixel intensity values to the background identification circuit. The background identification circuit studies and processes the luminance value of each raw input pixel value and the statistical model of pixel for the given or n^{th} real time image. The output computed pixel values and extracted parameters data are update the Statistical Model for future process.

For every raw input pixel, the Gaussian parameters mean standard deviation and variance are estimated from an external memory and processed to update the reference parameters stored in the memory for future process. This circuit is implemented to avoid the false triggering in the CCTV applications and also it updates the background reference data memory with the help of memory supervisor. This model can be analyzed by step by step by processing each sub modules of background circuit as shown in the figure 5.

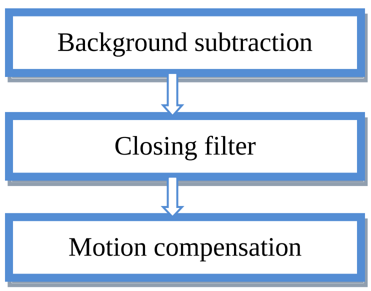

Figure 5: Sub Modules of background identification circuit

4. PROPOSED MATHEMATICAL FORMULATION FOR THE BACKGROUND IDENTIFICATION MODULE

The flow chart represents the design flow of proposed work as shown in the figure 6. After capturing the real time video sequence, Consider nth frame of the real time video as Input captured image sequence as In. i.e. In(i,j) is the pixel value of ith row and jth column of nth frame in the real time input sequence. The queue memory Q(i,j) having size N is formed for those In(i,j) pixels. S(i,j) is the total sum of pixel values and A(i,j) is average of pixel values are maintained over the incoming real time image sequences. The required number of frames sequences N can be chosen as per our requirement for modeling a static reference background image. Initial frame we choose for an input sequence will be n=1.

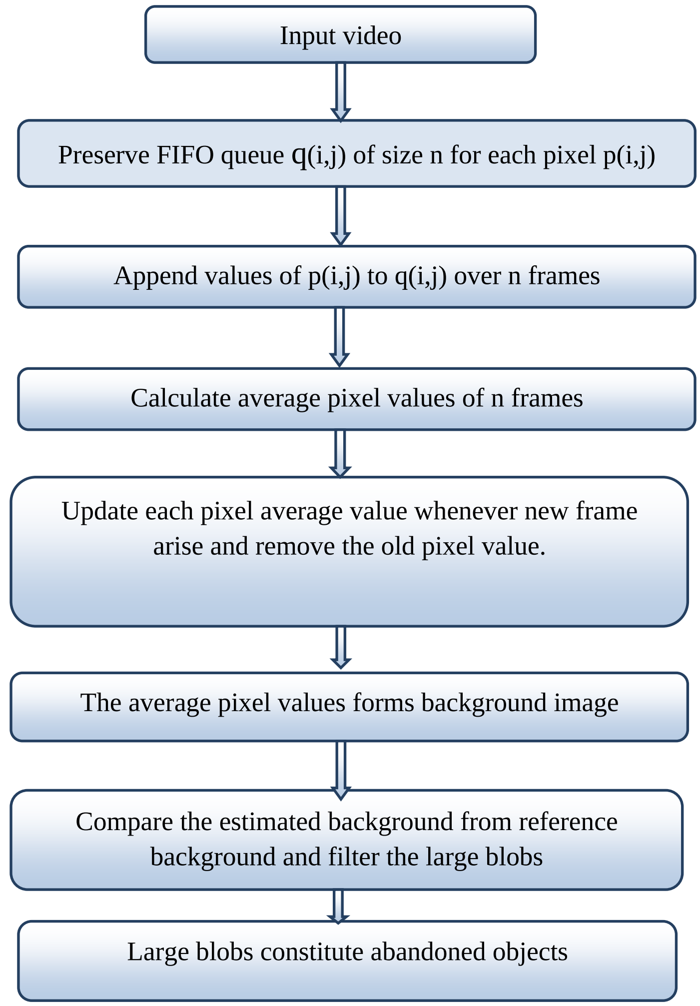

Figure 6: Proposed Flow chart

Background subtraction module: The real time captured pixel value and the background image pixel values are the given as input to this module. These two data's are processed to identify or detect the object which is in motion compared with the reference threshold pixel value. Table 1 shows the working process table of the background subtraction module

Table 1

RST	EN	A	B	T	A-B	OUT
1	X	X	X	X	X	0
0	0	X	X	X	X	0
0	1	M	N	Q	M-N > Q	255
0	1	P	Q	Q	M-N < Q	0

The RTL top view of background subtraction module is as shown in the figure 7 below. This module plays important role in detection of the object. The object detection is done by subtracting the real time captured image with the background reference image. The threshold is varied to find the object clearly visible.

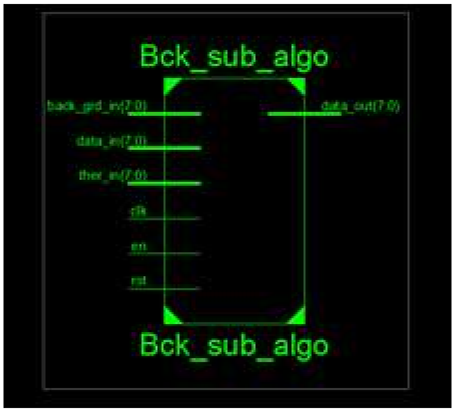

Figure 7: RTL Schematic block diagram of background subtraction

Closing Filter: Processed object which is obtained in the Bg module is in motion effect which has to be processed in order to remove the distorted or unwanted pixel (noise). The general block diagram of closing filter is shown in the figure 8.

Motion compensation block: The actual object which is in motion is obtained from the motion compensation module. Output of this block is the image pixel values which are undistorted and smoothened in nature. Table 2 shows the working process table of the Motion Compensation module.

Table 2

RST	A	B	CONDITION	OUT
1	X	X	X	0
0	M	N	M=255	N
0	M	N	M!=255	0

Internal RTL schematic diagram of motion compensation module is as shown in the figure 9 below. Output of background subtraction is given to motion compensation module. The object detected from the subtraction module may or may not be truly identified in nature. Due to noise, object which are in motion (moving). The detected object required fine tuning, preprocessing operation which will remove the unwanted / distorted pixel and helps in attributes extraction, smoothing, filtering . Motion compensation block will help in preprocessing process to identify the exact object.

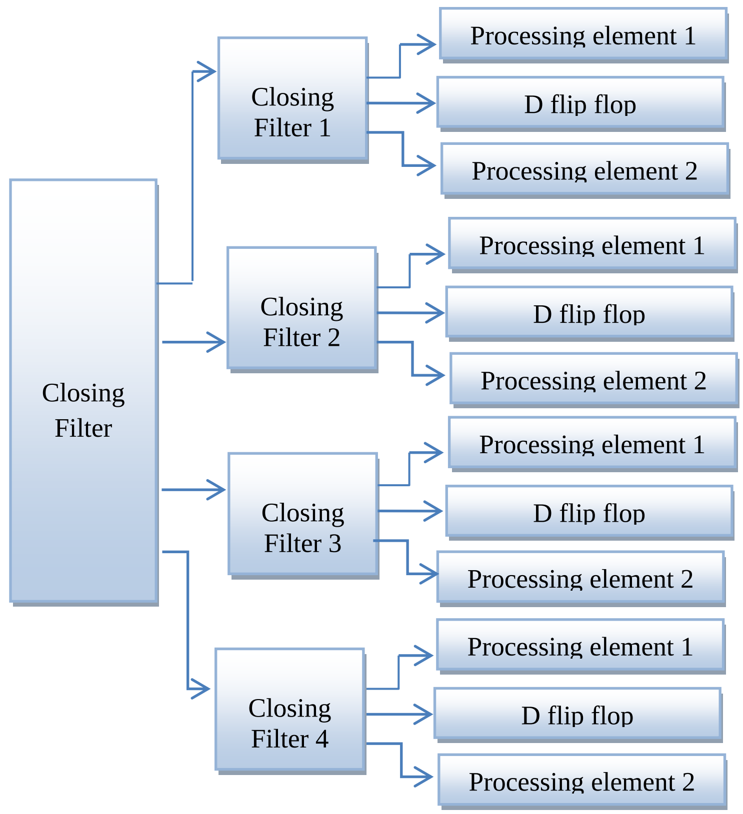

Figure 8: The general block diagram of closing filter.

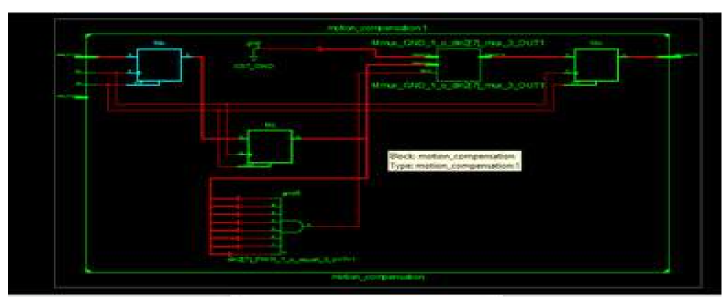

Figure 9: the RTL schematic of internal block diagram of motion compensation module.

5. BACKGROUND UPDATATION

Feature extraction is used for registering new background. After the motion object is detected. Its feature is extracted by means of mean, standard deviation and skewness-kurtosis factors. In this paper we have implemented small artificial neural network (ANN) for training and checking fitness for the design and finally background is updated which will helps to reduce the false triggering. The below block diagram fig 10 shows the different layers of ANN module.

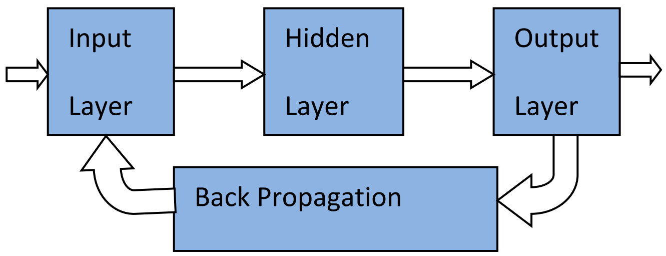

Figure 10. ANN internal architecture

The RTL schematic of the sub module of the hidden layer from ANN module is as shown in the figure 11 below.

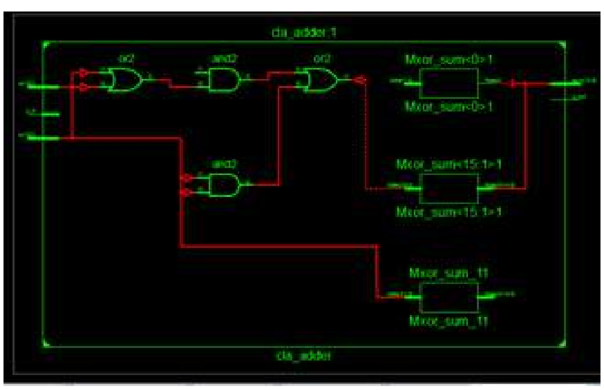

Figure 11: The RTL schematic of internal block diagram of hidden layer.

6. RESULTS AND COMPARISONS

FPGA implementation synthesized results shows that there is only 4% of total device utilization and memory block consumes 1% of the total devices utilization which is clearly observed in the table 3.

Table 3: Table shows design summary of 3X3block memory generation.

Device Utilization Summary			
Logic Utilization	Used	Available	Utilizations
Number of Slice Registers	2353	126800	1%
Number of slice LUTs	4800	63400	7%
Number of fully used LUT-FF pairs	1080	6073	17%
Number of Bonded IOBs	19	210	9%
Number of BUFG/BUFGCTRLs	1	32	3%

Screenshot of the color conversion module results are observed and verified, as shown in the figure 12 below.

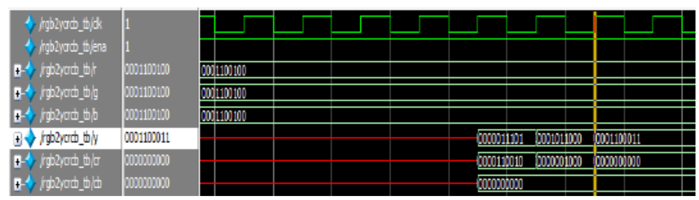

Figure 12: the simulation result of color Conversion

The figure 13 shows the simulation result of background subtraction module. This module is tested and verified for different basic data's.

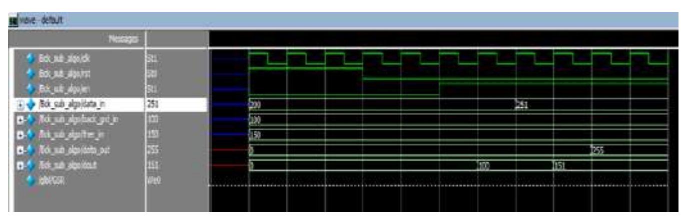

Figure 13: simulation results of background subtraction module.

Closing filter module is tested and verified for various basic data's. The simulation result of closing filter for a basic data is shown in the figure 14.

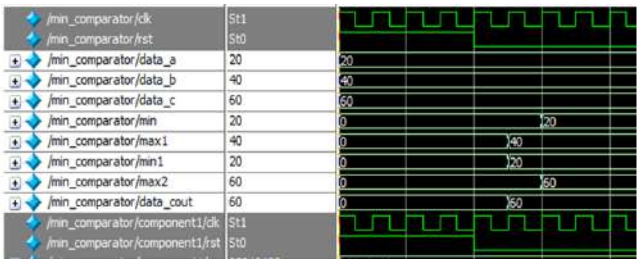

Figure 14: simulation result of closing filter

Motion compensation module is tested and verified by providing basic data's as input. The simulation result of motion compensation module is shown in the figure 15.

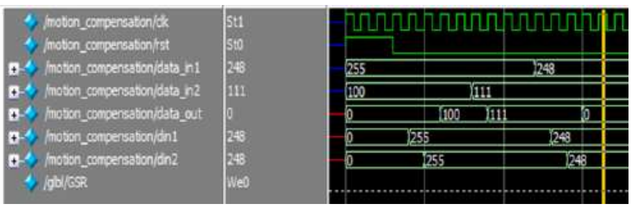

Figure 15: simulation result of motion compensation module.

The total device utilization of ANN top module is given in the table 4. We can observe, consumption is 3% of the total device.

Table 4: Design summary of ANN top module

Device Utilization Summary			
Logic Utilization	Used	Available	Utilizations
Number of Slice Registers	4364	126800	3%
Number of slice LUTs	9326	63400	14%
Number of fully used LUT-FF pairs	1257	12433	10%
Number of Bonded IOBs	19	210	9%
Number of BUFG/BUFGCTRLs	2	32	6%

RTL simulation results of ANN are shown in the fig 16 below.

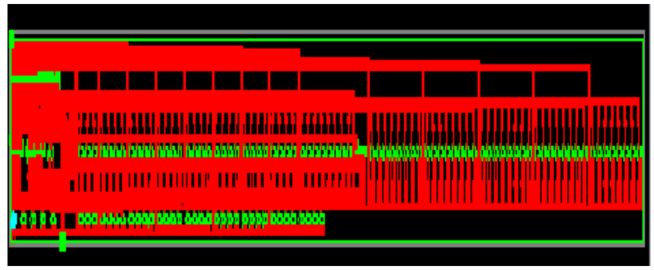

Figure 16: Simulation results of ANN module

The proposed work is simulated by comparing the values of input image pixel values with the reference pixel values of background image. If the real time input image and reference background image are same then the output will be black image (having all pixel values as zero value). If the input image and reference image are not same, then the output will not be black image. Output image is captured with different threshold values with clear identification of object and also shadow is completely nullified with respect to threshold values as shown in the figure 17.

Figure 17: Proposed work results are captured with different threshold values.

Based on the object detection in a dense populated area, many of the researchers have worked using different algorithms to achieve the best approximation. The table 5 [14] shows the list of algorithms experimented for different Threshold [T] values to detect the object. The other important parameter to be considered is the time taken for executing the task. Table 6 [14] shows the time taken by each algorithm to complete the task. Thus object detection in terms threshold and execution speed, MBNet algorithm is considered to be the reference to our work. The proposed system is estimated to complete the execution process within the stipulated time of 27 at the maximum threshold value.

Table 5: comparison data analysis of object detection rate (in %) for various methods [14]

Model	Threshold				
	T1	T2	T3	T4	T5
RCNN	76.2	71.2	65.4	59.2	54.3
Faster RCNN	82.9	78.0	71.3	66.2	61.7
SSD	79.7	74.1	70.6	66.2	61.2
Mask RCNN	80.6	76.5	72.0	65.6	63.3
SINet	86.5	83.0	78.6	70.2	63.3
YOLOv 3	85.9	80.3	75.3	71.3	65.1
MBNet	88.2	83.4	77.9	71.7	64.2
Propose d Work	90	85	80	70	60

Table 6: comparison of execution time to detect the object for various methods [14]

Methods	Time
RCNN	31.30
Faster RCNN	125
SSD	60
Mask RCNN	78
SINet	66
YOLOv3	40
MBNet	30
Proposed work	27

The proposed design is implemented on Virtex 7A100T-3CSG324 and the results are compared with the other previous design and tabulated. The results are compared with two parameters, first is percentage of success in identifying the object which is tabulated in the table 5 for different threshold value. We can observe the success rate of detecting the object increases as the threshold value increases. Second parameter is the time consummation to identify the object. Processing speed is tabulated and we observed that the time taken to identify the object is very less which can be seen from the figure 18. With the above comparison results we may say that our proposed design is fast and efficient FPGA design.

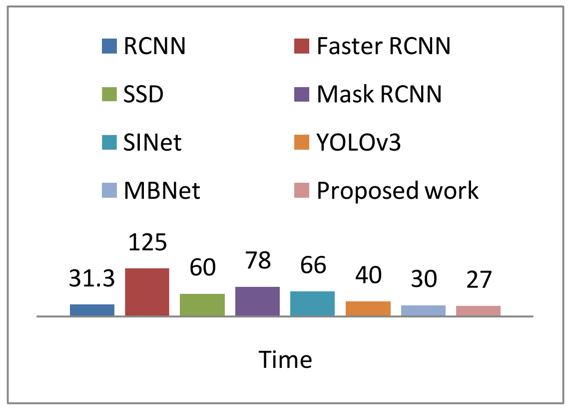

Figure 18: Graphical representation of time elapsed to detect the object

CONCULSION AND FUTURE WORK

We have developed an efficient GMM algorithm to be implemented on FPGA that is capable of performing an operation of moving object detection for the standard video in dynamic environment conditions. The design works perfectly for the various lightening conditions in full day time. Hence it is capable for the outdoor usage or for monitoring in public places which is one of the major concerns these days. In this paper we have discussed all the internal modules that were used in the development of the algorithm for the implementation and can conclude that the design is effective in terms of area on FPGA which is only 15% of the device utilization for virtex7 Xilinx FPGA. And also, the timing has been improved for the in comparison to the previously implemented GMM algorithm. All the simulation results mentioned in the paper are verified for the behavioral functionality and meeting all the aspects of the requirements. The synthesis results obtained in the paper are based on the Xilinx Design suit. The design is perfectly suitable for the hardware real time implementation which is our next goal. We are working on the images obtain from various sources to see the compatibility with night camera and conditions.

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