Video-Object Detection using Background Subtraction in Spartan 3 FPGA Kit

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***Abstract* — In many real time applications, detection of moving objects is necessary. But while post processing, the computational complexity has to be minimum. This work has hardware based moving object detection using background subtraction method for soft real time application is proposed. It aims in performing the automatic detection of moving objects using FPGA hardware with very high performance as well as low cost. With the help of a background reference image, the moving object can easily be detected using background subtraction method. A reliable background updating model is established based on the available data. This gives an accurate and efficient detection of moving objects. Also Sobel's edge detection algorithm is performed to trace the outline shape of the detected moving object. It is implemented using MATLAB tool and Xilinx ISE in Spartan 3 FPGA kit. RS 232 serial port cable is used for establishing the connection between hardware and PC. Visual basics software is used to view the output in PC.**

Keywords—Background subtraction, FPGA, Motion detection, Surveillance, Xilinx

I. Introduction

Digital Image Processing is an important aspect of object tracking and surveillance. The process of monitoring the behavior of people, objects or processes for security or social control is termed as surveillance. Visual surveillance is often done for various safety reasons using CCTV cameras. Similarly Clinical surveillance is done for monitoring and diagnosing diseases. Detection of Moving objects is necessary for surveillance. It helps us to determine the shape, size, position of tumors, etc. in clinical surveillance. Likewise, the motion detection is used for various safety reasons like identifying thefts in closed shops, to raise alarms in isolated areas, detecting suspicious activity, airport security, military applications, etc.

In the past decades various software or hardware based techniques were used to detect the real time motion. It is necessary to maintain the processing time per frame as minimum as possible to monitor the objects in real time environment. Also the computational complexity has to be very less as it involves continuous processing of data. So, the techniques which we are using should be very simple and efficient. For this purpose background subtraction algorithm is used. Background subtraction based algorithm is highly efficient, offers high performance in terms of accuracy and has very less computational complexity. In this technique the moving objects is detected by performing the absolute difference of the foreground image with the moving object and the background image.

There are various constraints in the detection of moving objects. The changes in illumination of the outdoor environment will have an effect on the background image [1]. When an object moves towards or away from the camera, its size may vary. The background image itself may be a non-static background consisting of flying birds, motion of trees, etc. [2] such constraints related to the backgrounds, limits the system to monitor only certain areas. But in most of the circumstances unconstrained environments are the required monitoring area. In all these cases, the background subtraction algorithm can be used to detect the moving object in a very efficient manner. A background model is created and updated for the motion detection.

The organization of the paper is as follows: The proposed design is discussed in section 2, its implementation in section 3, Result and discussion in 4 and conclusion in section 5.

II. Proposed Design

Background subtraction algorithm follows a general pattern of processing which includes pre-processing, background subtraction and post processing.

A. Pre-processing Unit

Pre-processing stage is a filtration stage in which the raw input video is converted to an appropriate format which can be processed. Preprocessing is mainly performed to reduce camera noise, smoothing of the images and to remove transient environmental noise like rain.

B. Background Subtraction

Initially, the video is converted to frames depending on its frames per second value. Then the video frames are observed and used for calculating and updating the background model. The image without any object of interest serves as a reference for the background subtraction algorithm. Later, foreground detection is performed to identify the foreground which consists of the moving object to be detected. Based on this the required two images are selected which are background image and foreground image. Various rules are defined for the maintenance of background model [3].

Principe 1 (Semantic Differentiation)–The background maintenance module should not handle semantic differentiation of objects. This will prevent the incorrect mapping of foreground objects as background or vice-versa.

Principle 2 (Proper Initial Segmentation) – Background subtraction algorithm must segment the object to be detected when they first appear or reappear in a video. This condition

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reduces the computational complexity of the algorithm as there is no need to perform the background subtraction for each frame in a sub-region.

Principle 3 (Stationary criteria) – A background is not characterized by the absence of motion. A moving object is considered as foreground if it deviates from the necessary properties of the background. Thus a pixel level stationary criteria has to be emphasized which will declare the background and ignore the rest.

Principle 4 (Adaptation) – The adaptation for the changes in the background are necessary for the maintenance of the background model. This adaptation helps in differentiating the foreground image and the background image easily.

Principle 5 (Multiple spatial levels) – A Background model should consider the variations at different spatial scales. The changes that happen at both pixel-wise models and frame-wise models should be analyzed for efficient result.

The images are converted to one dimensional Grayscale image and then converted to header file format for background subtraction. And then the background subtraction algorithm is written in the Xilinx Platform Studio (XPS) tool by using impulse 'C' language.

$$\text{MovingIm}(i, j) = |\text{Foreground}(i, j) - \text{Background}(i,j)| \quad (1)$$

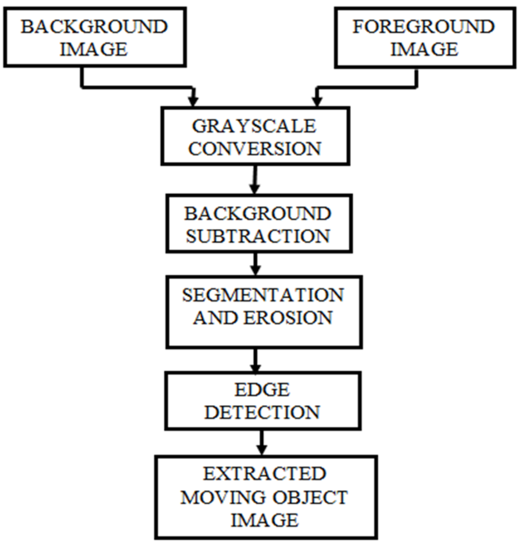

Figure 1. Flowchart of Background subtraction design

C. Post-processing Unit

In the post-processing unit, morphological operations are carried out to obtain an accurate image of the moving object. It includes the segmentation operation in which each pixel value is compared with a predefined threshold value. This helps in removing the unwanted noise. Then erosion operation is performed by using 3*3 structuring element to extract the eroded image from the segmented image. Then the image is processed to detect object edges. Edge detection is an important process to obtain a clear outline shape of the detected moving object. The algorithm that is used in edge detection is Sobel's edge detection algorithm [4].

III. IMPLEMENTATION

The proposed system is implemented using MATLAB tool and Xilinx Platform Studio (XPS). Impulse C language is used for Background subtraction algorithm and it is implemented on Spartan 3 EDK board using RS 232 serial port.

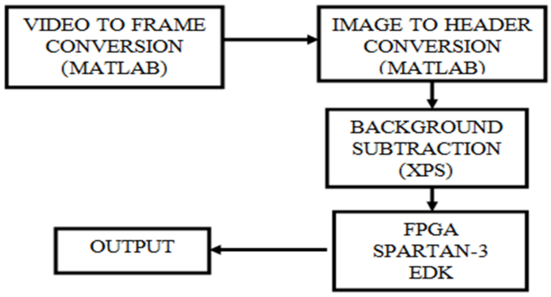

Figure 2. Implementation of Background Subtraction Algorithm

A. Frame conversion and Grayscale conversion

Initially the video is slowed down with respect to the frames per second of the video. Then the video is converted to the frames in Matlab tool. This process is done to extract the images that are required for the further processing. We select the background image and foreground image from the separated frames. Processing an image with three attributes namely red, green, blue (RGB) has numerous difficulty in recovering the exact image after processing. Thus we convert an RGB image into a grayscale image for easy analysis. A grayscale digital image carries the information in terms of intensity varying from white at the strongest intensity to black at the weakest. Weighted method of Grayscale conversion is used.

$$\text{GImage} = (0.3*R)+(0.59*G)+(0.11*B) \quad (2)$$

B. Header Conversion

For the selected background and foreground images, after grayscale conversion, header files have to be generated for the further processing of background subtraction. The grayscale images are a one-dimensional image which is generally considered as 8 bits per sampled pixel and it allows 256 intensities of varying shades of gray. Based on these intensity values for each pixel, the header file for the image is easily generated in Matlab tool.

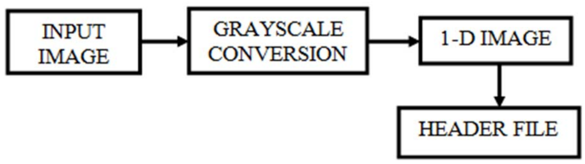

Figure 3. Header conversion

C. Background Subtraction Algorithm

For the created header file of the background and foreground images background subtraction is done. An algorithm for background subtraction is written in XPS. XPS tool is used to link the program to the hardware Spartan 3 FPGA kit. The header files are given as input to XPS. With the help of RS 232 serial port we establish a connection between PC and the hardware. Visual basics application is used to view the output image in PC.s

D. Morphological operations

Initially, on a background subtracted image segmentation process is performed. Each pixel is compared with the predefined threshold value and when the difference value is above the threshold, it is considered as one or else zero. It is followed by erosion operation in which a 3*3 structuring

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element is used to to remove the pixels from object boundaries. The structuring element contains all 1's. Then Sobel's edge detection algorithm is used to detect the edges of the object to be detected. It consist of 3*3 convolution kernel one for each X and Y direction. It finds out the difference by placing the kernel matrix over each pixel of the image. We get two output images each for X- Direction and Y-Direction which is then combined together to form a new image which represents the sum of the X and Y edges of the image. By using Kernel Convolution we can detect the edges.

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

Gx

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

Gy

Figure 4. Sobel's convolution kernel

IV. Results And Discussion

The input video is converted to the frames in Matlab tool. This helps us to separate the foreground and background image from the video for further processing. It is shown in Fig 5.

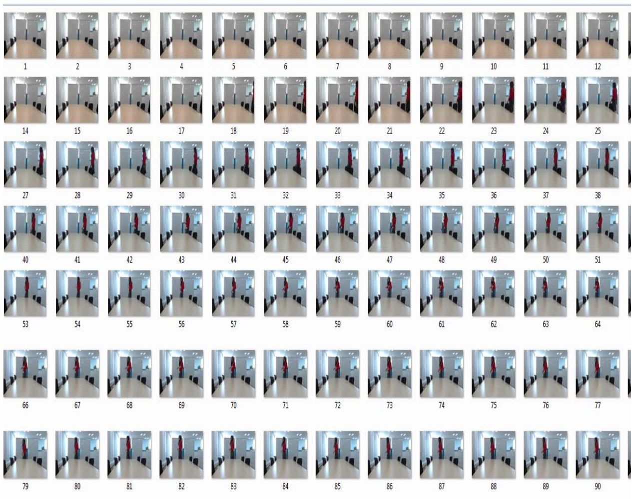

Figure 5. Frame conversion

Background and foreground images are selected and are converted to Grayscale for easier processing. Grayscale conversion of the background image is shown in Fig 6.

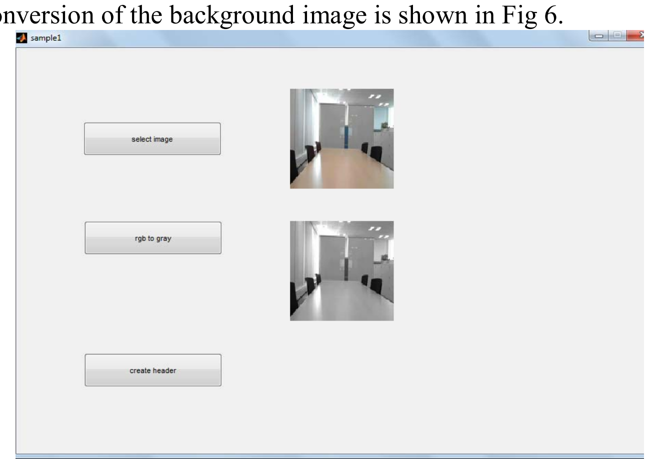

Figure 6. Grayscale conversion of Background Image

The Grayscale images are converted to header file format using Matlab tool. When header file for the image is created a dialog box appears on the screen confirming the process. The header file created for the foreground image is shown in Fig 7.

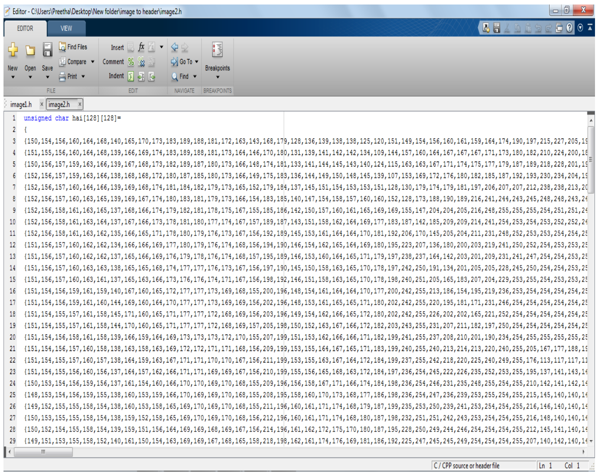

Figure 7. Output of Header file of Foreground Image

The header files for both the images are processed in Spartan 3 kit using XPS tool to get the output of the detected object. The communication between the hardware and PC is established using RS 232 serial port. Fig 8 and Fig 9 shows the background image and foreground image as viewed in visual basics window.

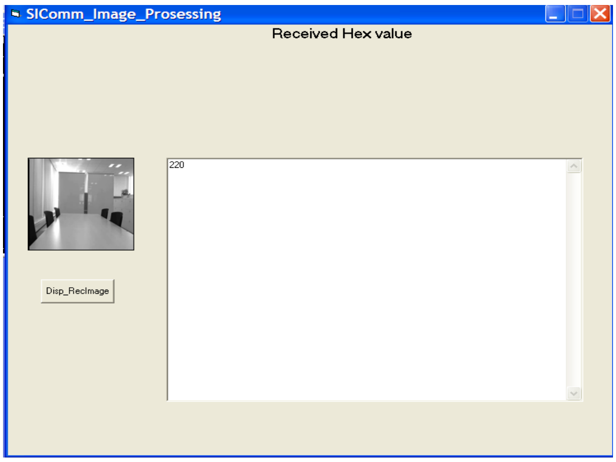

Figure 8. Background image in Visual basics window

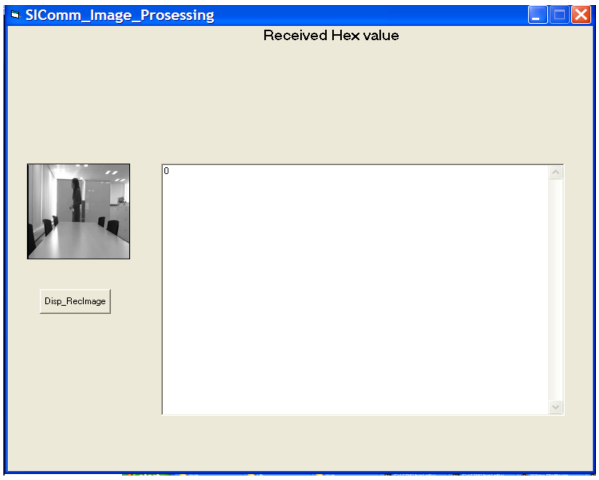

Figure 9. Foreground image in visual basics window

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The background subtraction is performed on the header files of both the images. On the background subtracted image, the morphological operations like segmentation, erosion and edge detection are done to obtain the moving object. The final output after the background subtraction and morphological operations are shown in Fig10.

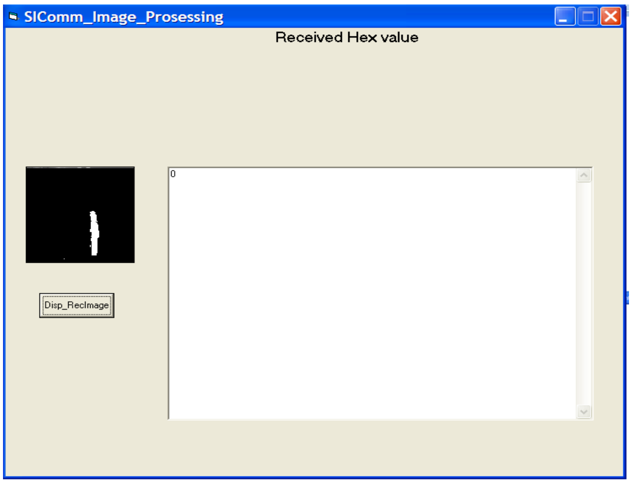

Figure 10. Output image of the detected moving object

V. CONCLUSION

Background subtraction algorithm is efficiently identifying a moving object with least complex calculations. The proposed system is implemented in a low cost FPGA and it presents good results. The execution time is also very less as the computations are done concurrently. The moving object is detected accurately along with the outline shape of the object.

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