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Development of an FPGA Based Embedded System for High Speed Object Tracking

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Abstract: This paper deals with the development and implementation of system on chip (SOC) for object tracking using histograms. To acquire the distance and velocity information of moving vehicles such as military tanks, to identify the type of target within the range from 100 m to 3 km and to estimate the movements of the vehicle. The VHDL code is written for the above objectives and implemented using Xilinx's VERTEX-4 based PCI card family. *Copyright © 2010 IFSA.*

Keywords: FPGA, Embedded System, VHDL, Object Tracking, Image Processing

1. Introduction

The present work is aimed at hardware implementation of image histogrammer used for calculation of infrared (IR) image targets in military applications. Code is developed in VHDL for parallel processing of IR images. 2-D histograms are useful for position determination of desired objects in the images obtained from monochrome IR CCD Cameras. The problem is focused towards the processing of monochrome images. Further, image segments of 64 x 64 pixels frames are considered for optimal design, and implementation could be generalized to 512 x 512 pixel frames images.

The advanced state of art tools employed in the project are MATLAB-7 and VHDL (Ver. Xilinx7.1 Platform). The actual problem is verified and the solution methodology has been, initially, developed in MATLAB. This conceptual modeling enables us in hardware implementation of the problem clearly and quickly. Further, the time optimization of algorithm could be verified. The MATLAB model is

then transformed to VHDL coding. The realization is made on Xilinx's Vertex-4 FPGA chip to implement the parallel processing of image Histogrammer processor.

The application of image histogram is to estimate the velocity of moving objects, which are in the range of 100 meters to 3000 meters away from the tracking system. The technique is especially useful in tracking of military tanks in missile applications. The dynamic motion of the missile could be tracked and controlled through the feedback loop. The CPU control system is shown in Fig. 1. In this application, the image histogrammer constitutes the Image Processing block.

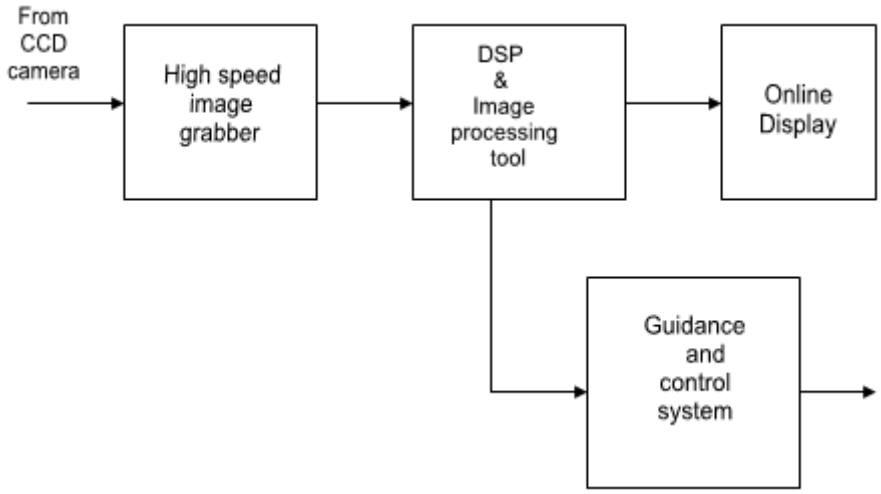

Fig 1. Block diagram of object tracking control system.

2. Velocity Estimation using Image Processing

The image processing of 2-D image histogram can be used to estimate the velocity of a moving object (like military tanks). Velocity estimation plays an important role in automatic tracking applications. The identification of the target is based on captured image movement analysis. One of the approaches used for velocity estimation is by the histogram analysis of the images of the moving targets by using image-processing tracking techniques. Very high speed image processing involves processing and analyzing the images by various image-processing techniques depending upon the time and type of application. These images are generated by an Infra Red Charge Coupled Device (IR-CCD) camera.

The parallel processing system-on-chip blocks involve two consecutive image data frames (64X64), which are stored in the RAM. The processing involves pixel by pixel parallel operations. The frame subtracted values are stored in the third frame. Then X, Y histograms are calculated for the resulting image. Then the moving average filtering (smoothing) is done over histograms. Finally to obtain the maxima "Find maxima Index" algorithm has been developed. The difference between two maxims of successive frames X-histogram gives the Δx and the difference between two maxims of successive frames Y-histogram gives the Δy, which can be used to calculate the velocity of moving objects.

The difference in recording times of the two frames gives the
Time interval of the motion of object as $\Delta \mathbf{t = T2 - T1}$

Velocity of the objects in X-direction (V_x) = **dx /(t2 – t1)**
Velocity of the objects in Y-direction (V_y) = **dy / (t2-t1)**
Where **t2-t1 = Δt = 1 / (Frames per Sec),**

where T is the time taken by the object to move from first position to second position, that can be calculated from the frame frequency (~30 frames/sec), i.e.,

$$T = 1/\text{ Frame frequency}$$

Δx = displacement moved horizontally with respect to the previous frame in Δt time.
Δy = displacement moved vertically with respect to the previous frame in Δt time. The overview of the object tracking system is shown in Fig. 2.

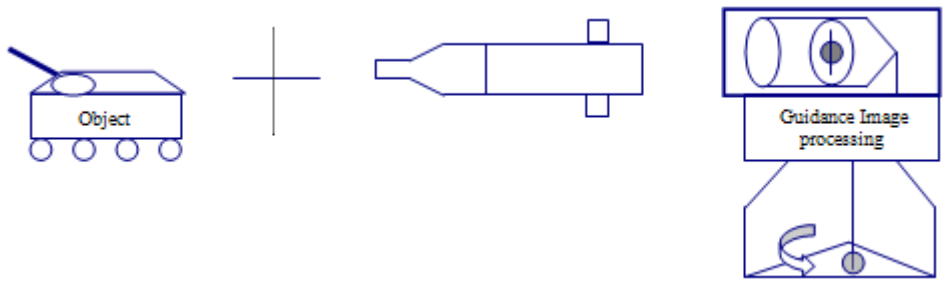

Fig. 2. Overview of the object tracking system.

3. Design Approaches

Fig. 3. shows the basic inputs and outputs of the VLSI histogrammer with smoothing filter chip that has been developed in the present study.

Fig. 3. The Image Histogram System-on-Chip.

The frames are obtained from the CCD camera into an image grabber memory. There is proper synchronization between the two. For each clock pulse, two consecutive frames are read into the histogram calculation chip for processing. The entire operation is carried on when the chip is enabled. After processing the position of the desired object are to be output. These correspond to the indices of the vertical and horizontal maxima.

The block diagram showing the basic operations is shown in Fig. 4 and the flowchart of the system's software is shown in Fig. 5. The 2-D image histogrammer implementation contains mainly three important steps of processing to be made on the image:

- Obtaining horizontal and vertical histograms
- 2-point moving averaging of the two histograms
- Finding the maxima and their indices.

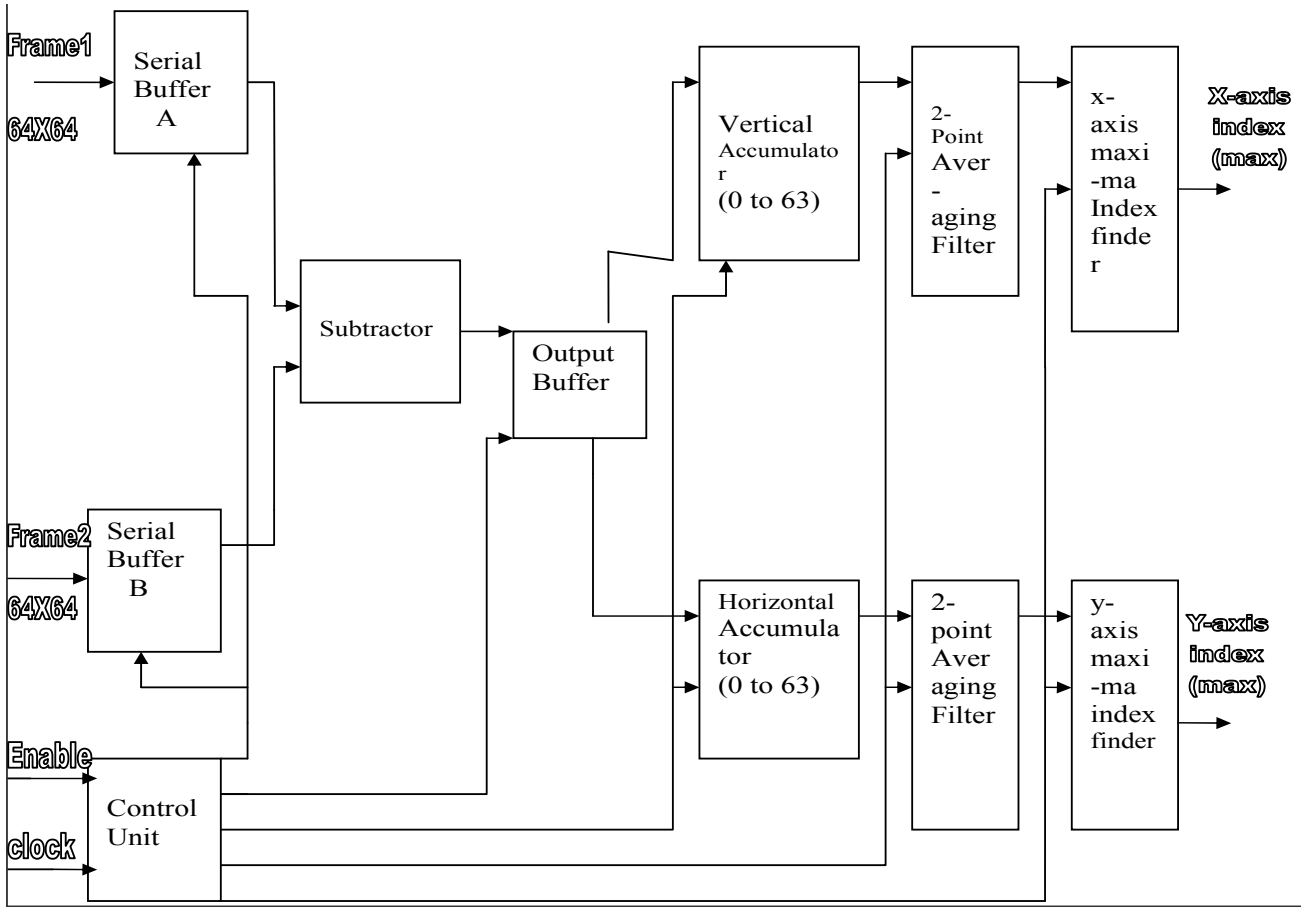

Fig. 4. Processor Block Diagram.

In real time applications, we generally encounter 512 x 512 pixel images. The operation performed on one 8-bit pixel data is common to all the other pixel data in the frame. Therefore in the entire explanation, constraint is made to 64 x 64 frame data instead of 512 x 512 frames.

The sequence of steps during development of System on Chip is as follows:

Two consecutive frames of source image which is captured online using CCD is taken. The basic unit is developed for 64x64 2-D image segments. This can be generalized for 512x512 images. The estimation of real time velocity information of the objects is performed by frame subtraction and X, Y histograms methods using MATLAB signal processing tool box. Modeling of this problem is developed in VHDL code for the calculation of real time histogram of a digital image. Finally VHDL implementation is accomplished. The online captured image data frames are processed "Frame by Frame" within 20 ms to 120 ms times using high speed FPGA based vector processor.

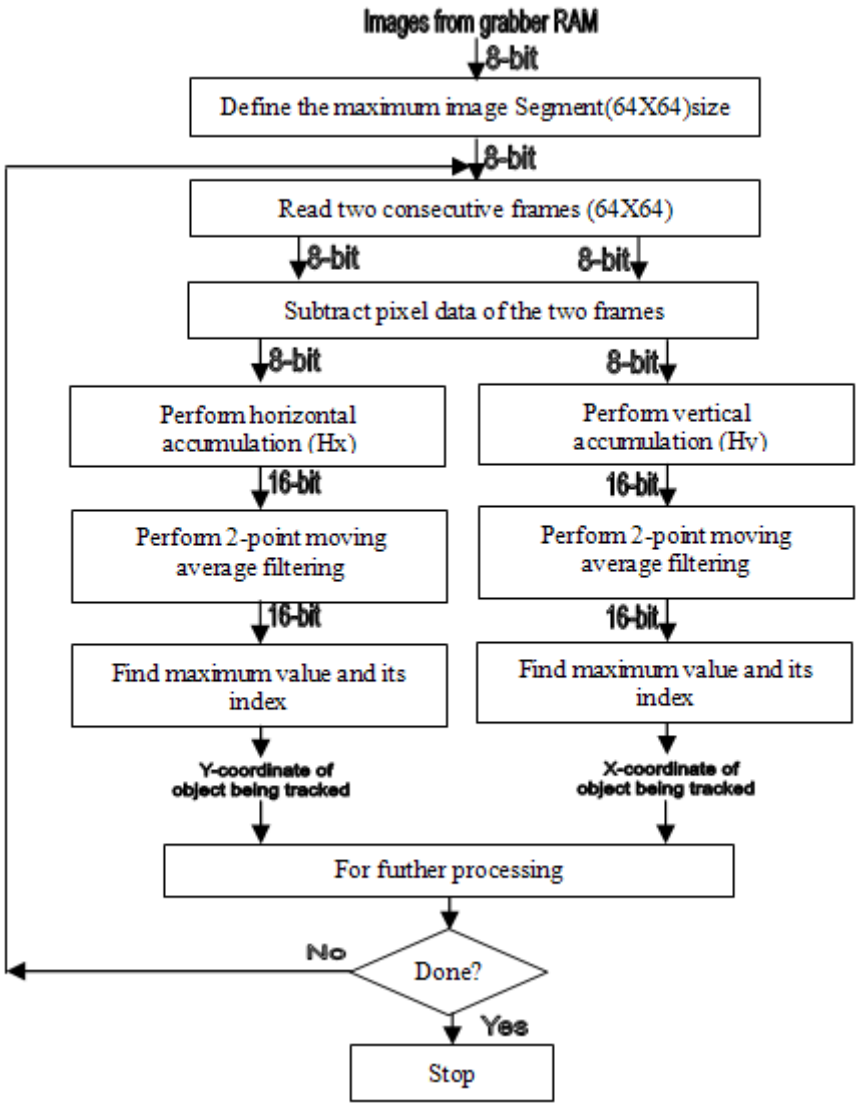

Fig. 5. Flowchart for Image Histogrammer.

4. Conclusion

The complete digital hardware (processor) has been realized on an FPGA chip using VHDL. The simulation software for motion analysis has been developed using MATLAB programming language. The software was found working well on FPGA based PCI cards for different moving objects. It could analyze images and determine various motion related parameters like path or trajectory, velocity, acceleration and direction of movement for any object or target. The software has been made rugged against blurred images and images with noise as a case, an application for error measurement in aiming a moving target has also been developed.

The software can also be used in automatic video tracking applications, Post processing of the tracking software can be used to generate control signals that drive missile seeker assemblies, keeping the IR imaging sensor for target tracking.

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Guide for Contributors

Aims and Scope

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- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
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