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Character Recognition System Using Xilinx System Generator

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ABSTRACT

Nowadays, bulk of printed documents are available in libraries, information centers, museums and offices which creates an increasing demand of Character Recognition. Character recognition is an area of research where many researchers have presented their work and it is still an area under research to achieve higher accuracy. This paper aims to present a technique for character recognition using edge detection. Initially the main goal is to carryout hardware implementation of edge detection technique using Xilinx System Generator. In this paper three different methods namely direct correlation with segmented templates, MATLAB edge detected image with edge detected templates and Xilinx System Generated Hardware co-simulated output image with Xilinx System Generated templates are compared. It is concluded that the accuracy of edge detection correlation technique is better than direct correlation technique. For edge detection Sobel operator is used. For hardware co-simulation Spartan 3E and Virtex 5 FPGA Boards are used.

Keywords--- Xilinx System Generator (XSG), Optical Character Recognition (OCR), SobelEdge Detection, Template Matching, Hardware Resource Utilization

I. INTRODUCTION

Digitizationof printed documents are becoming progressivelyimportant to have information available in digital format for increased efficiency in data storage and recovery, and optical character recognition (OCR) is being known as one of valuable input devices in this respect[1] [2]. The expansion of information technology supports faster, more powerful processors and high speed output devices (printers and others) to generate more information at a faster rate. These days the availability of relatively inexpensive document scanners and optical character recognition software has made OCR an attractively priced data entry methodology[1].Optical Character Recognition is the process of translating images of handwritten, typewritten, or printed text into a format understood by machines for the purpose of editing, indexing/searching, and a reduction in storage size.

Efficient rapid prototyping system requires a development environment targeting the hardware design platform. The tools used are MATLAB R2011a with Simulink from MathWorks [4], System Generator 14.2 for DSP and ISE Design Suite 14.2[3]. In addition there are several cost effective development boards available on the market that can be utilized for the software design development phase. Xilinx System Generator is a MATLAB-Simulink based design tool for Xilinx's line of FPGAs. Complex digital circuits have been developed using multiple Hardware Description Language (HDL) modules. Because of the abstraction level is very low within the HDL environment, the difficulty increases as the design becomes more complex. System Generator is a design tool from Xilinx that allows the use of the Simulink for system design. It offers multiple features like Resource Estimation, Hardware Co-simulation and many more to improve performance. The entire design flow is shown in figure 1.

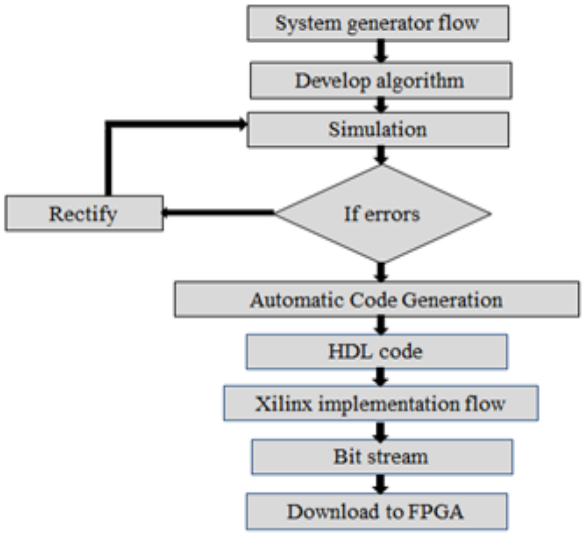

Figure 1: Design methodology with Xilinx System Generator

Maduria*et al.*[5] have presented a technique to recognize characters for number plates using edge detection. Four different operators like Sobel, Prewitt, Roberts and Laplacian of Gaussian (LOG) operators were used for edge detection. In this paper advantages and disadvantages of edge detection techniques was also discussed. Tiwari*et al.*[6]have proposed an OCR algorithm for English handwritten and text image. The scanned documents were pre-processed to extract lines. These lines were segmented to extract characters. The accuracy of algorithm was around 85% to 90%.Sobel edge detection algorithm was implemented on FPGA by Nguyen *et al.* [7]. In this paper, Sobel edge detection algorithm was implemented using XSG as well as Vivado_HLS tools. The hardware resources and power consumption was evaluated for both the tools. It also says that power consumption on Zynq-700 AP SoC spends more 30% by using Vivado_HLS than by using XSG tool and for Spartan 3A DSP consumes a half of power comparing with by using XSG tool. Engle *et al.*[8] have proposed hardware software co-simulation of edge detection for image processing using delay blocks. They presented image processing algorithms application to edge detection system in Xilinx System Generator with focusing on achieving low cost and short development time. Kavitkar*et al.*[9] have presented Sobel and Prewitt edge detection algorithm. They implemented it on Spartan3E FPGA board. They compare the both algorithms and concluded that Sobel edge detection algorithm is better suited for real time application over its contemporary Prewitt algorithm. While considering optimize power, area constraint and maximum frequency, Sobel architecture is more preferable then Prewitt architecture.

II. SOBEL EDGE DETECTION

Sobel edge detection algorithms are the most normally used technique in image processing for edge detection [10]. The Sobel operator is used to calculate the gradient of the image intensity at each point. It gives the intensity direction increasing from light to dark and the rate change in that direction. The Sobel kernels are given by

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & -2 & 1 \end{bmatrix} (1)$$

The kernel G_x is sensitive to changes in the x direction, i.e., edges that run vertically, or have a vertical component. Similarly, the kernel G_y is sensitive to changes in y direction, i.e., edges that run horizontally, or have a horizontal component. The two gradients calculated at each pixel (G_x and G_y) by convolving with above two kernels can be regarded as the x and y components of gradient vector. This vector is oriented along the direction of change, normal to the direction in which the edge runs. Gradient magnitude and direction are given by:

$$G = \sqrt{{G_x}^2 + {G_y}^2} \quad (2)$$

An approximate magnitude is calculated using

$$|G| = |G_x| + |G_y| \quad (3)$$

The angle of orientation of the edge giving rise to the spatial gradient is given by:

$$\theta = a\tan(\frac{G_y}{G_x}) \quad (4)$$

III. SYSTEM DESIGN

The input image is the string of all 36 alpha-numeric characters. Each letter is separated from the input image and then compared with remaining letters. The next step is to find the correlation of single input image character with all template characters, the letter which shows the maximum correlation with the letter in the template are saved on the notepad. The same steps are continued for all character.

The next part of the design is usingXilinx System Generatorfor Sobel edge detection. The edge detected characters are correlated the remaining edge detected characters to find correlation coefficient.

The system performance is evaluated is by finding the correlation coefficient of individual characters with remaining characters for different techniques. The character having maximum is written into the notepad. The design flow for the character recognition system is shown in figure 2.

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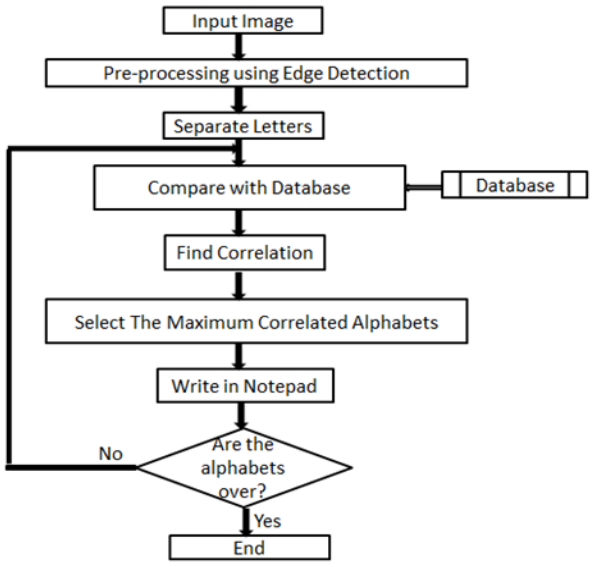

Figure 2: Design flow of proposed CR System

The steps in the character recognition system are discussed below:

A. Data Preparation

The input image is synthetically generated; it contains set of all alpha-numeric characters. In this way, ten databases for different fonts were created to evaluate the performance of the system. Figure 3 shows a sample input image.

Figure 3: input image to edge detection system

B. Pre-processing and edge detection

The main objective of the pre-processing is to organize the information so that the Character Recognition task become simpler i.e enhancement, noise removal and finally edge detection of the input image having string of all characters. The final edge detected output using XSG and MATLAB are as shown in figure 4 and figure 5 respectively.

Figure 4: output image after edge detection using XSG

Figure 5: output image after edge detection using MATLAB

C. Segmentation

Segmentationis an important stage in Character Recognition system because it affects the rate of recognition. In internal segmentation an image of sequence of characters is decomposed into sub-images of individual character as shown in figure 6.

Figure 6 : Segmented Images of output image after edge detection using XSG

D. Template Matching

This technique is different from others, in that no features are actually extracted. The matrix containing the image of input character is directly matched with a set of prototype characters representing each possible class. The correlation coefficient between the segmented character and each prototype is computed and the class of the prototype giving the best match is assigned to pattern. But, this technique is sensitive to noise and style variation and has no way of handling rotated characters. To measure performance of the system, the correlation coefficient between the original character and database of hardware edge detected images, original charcter and through software generated edge detected images is computed. Similarly a single character from one database is correlated with same character from all database.

E. Post processing

Post-processing stage is the final stage of the recognition system. It prints the corresponding recognized characters in the structured text form.

IV. IMPLEMENTATIONS

With Xilinx System Generator design flow[10],[11] there are three steps called software simulation (design the model within Simulink environment), hardware co-simulation (convert the simulation into hardware code or release bitstream file), and hardware implementation (download bitstream file into target FPGA platform). The Sobel edge detection algorithm is developed and tested on FPGA platform. The design flow is shown in figure 7.

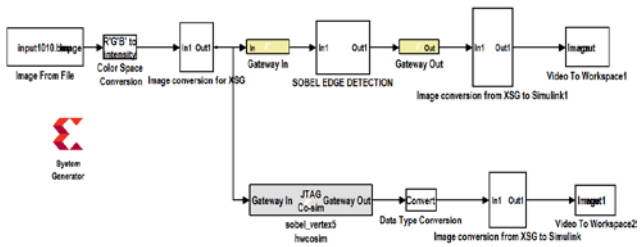

Figure 7: Sobel Edge Detection design flow based on XSG

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The hardware resources used for the edge detection operation are measured by the number of slice registers, number of slice LUT and number of bounded IOBs. When simulation results are correct, the implementation steps are done automatically by the block named as system generator token. The edge detection model was executed for two FPGA platforms viz Spartan3E and Virtex5. The hardware resource utilization, timing and power analysis for these two platforms is given in figure 8 and 9 respectively.

Device	Spartan 3E XC3S500e-4fg320			Virtex 5 VC5VSX50t-1ff1136		
	Used	Available	%	Used	Available	%
Number of Slice Registers	69	4,656	1%	64	32,640	1%
Number of Slice LUTs	69	9,312	1%	69	32,640	1%
Number of bonded IOBs	18	232	7%	18	480	3%
Maximum Frequency	50 MHz			100 MHz		

Figure 8: Device Utilization

Device	Spartan 3E XC3S500e-4fg320	Virtex 5 VC5VSX50t-1ff1136
Total Power Dissipation	107mW	720mW
Minimum Period	2.383ns	1.666ns
Maximum Frequency	419.639MHz	600.240MHz

Figure 9: Timing and Power Analysis

V. PERFORMANCE EVALUATION AND RESULTS

In normal and usual OCR systems, characters like C gives high correlation value with character like G, O, Q and 0. Character I gives high correlation value with character like J, L, T and 1.Similarlycharacter like O gives high correlation value with character like Q, D and 0. If we take edge detected version of these characters, they show less correlation with other edge detected characters. The characters C, I and O shows correlation valuewith all the characters are shown in figure 8, figure 9 and figure 10 respectively.

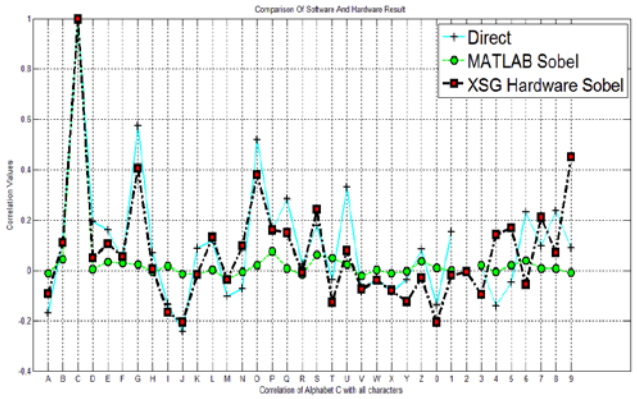

Figure 8: Correlation of CharacterC with all characters

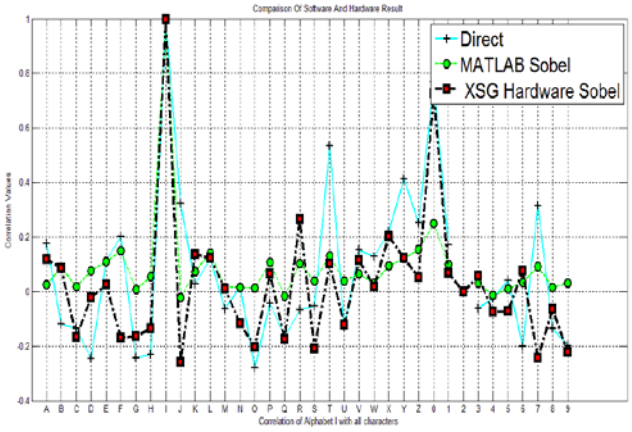

Figure 9: Correlation of character I with all characters

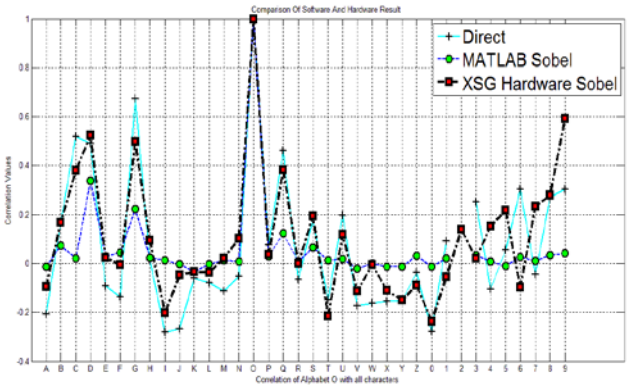

Figure 10: Correlation of character O with all characters

The system efficiency is proved using another way in which, the character present in the one database is compared with same character present in 10 different databases. Two techniques of edge detection one is MATLAB Sobel and other is Xilinx System generated Hardware co-simulated Sobel are compared for character I and O , as shown in figure 11 and figure 12 respectively.

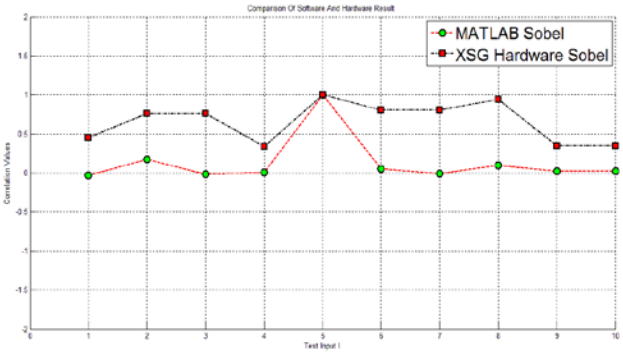

Figure 11: Correlation of Alphabet I with Alphabet I of 10 databases

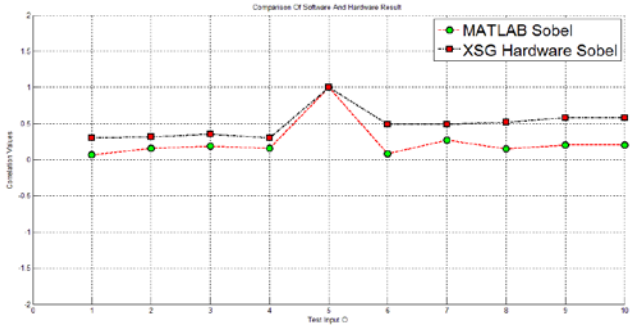

Figure 12: Correlation of Alphabet O with Alphabet O of 10 databases

The above Figures clearly indicate that correlation for the same character is higher in XSG model compared to MATLAB Sobel model, if different database having different fonts are used. XSG Sobel modelgives better results than MATLABSobel model. Hardware result is obtained with Spartan 3E and Virtex 5 FPGA Development boards.

VI. FUTURE SCOPE

Efforts can be taken to design whole system on FPGA. Accuracy can bemaximized by taking appropriate threshold correlation value. For real time system implementation,it requires less hardware utilization and power consumption. Such a system can be implemented on other platform such as VIVADO_HLS, Embedded Development Kit etc.

VII. APPLICATIONS

1. Barcode recognition: used in daily life and industries
2. Legal industry: for digitalizing the documents and directly enter to computer database such that we can made the image into searchable document.
3. Banking: process check without human involvement. A check is inserted into machine where system scan the amount to be issued and correct the amount money transferred. This technique reduces time in bank.
4. Healthcare: for recording the patient's data
5. Captcha: It is the program that can generate for only human can pass not the computer program cannot do, OCR system can be used to remove this noise and segment the image to make the image and make typed text acceptable.
6. Digital library:sharing the teaching materials
7.Automatic Number Plate Recognition:vehicle verification, toll collection, pays per use road

VIII. CONCLUSION

It is concluded that results obtained with correlation values for group of similar characters using edge detection by Xilinx System Generator are better than results obtained for correlation values usingdirect correlation. Direct correlation of input image having characters of different font, than template character, does not give sufficient matching as edge detected image is correlated with edge detected template. Input image containing string of all characters is converted into storable and searchable file in the form of text file. Xilinx System Generator is a very useful tool for developing computer vision algorithms.

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