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DESIGN AND MODELING OF LINEAR BACK PROJECTION (LBP) ALGORITHM FOR FIELD PROGRAMMABLE GATE ARRAY (FPGA)

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ABSTRACT

This paper focus on designing and modeling of linear back projection (LBP) algorithm for field programmable gate array (FPGA) application. The features provided in FPGA make it the most suitable for embedded system for optical tomography system in data acquisition system. The language supported by FPGA is a Hardware Description Language (HDL). However, manual coding for HDL code spend more time to program. In addition, it increase chances of human error. Therefore, the usage of Matlab Simulink has encouraged many researchers to use it in order to generate HDL code while minimize human error. The LBP algorithm is designed by using Matlab Simulink. From the Matlab Simulink, the HDL code will be generated automatically by using HDL coder which is provided by MathWorks. The HDL code obtained will be downloaded into an FPGA platform of Altera DE2-115. The result obtained shows that the LBP algorithm has been successfully modelled. Therefore, this approach provides an effective method flow for the LBP algorithm to implement in FPGA.

Keywords: field programmable gate array, hardware description language, matlab simulink, linear back projection algorithm, HDL coder.

INTRODUCTION

Linear Back Projection (LBP) algorithm is an algorithm that widely used in optical tomography system. This LBP algorithm is implemented in optical tomography in order to obtain the concentration profile of tomogram image [1]. The concentration profile is obtained from a combination of data projection for each sensor with its computed sensitivity map.

LBP algorithm is easy to implement compared to other algorithms. Moreover, it has become popular method among researchers due to low computation, simple and fast respond algorithm [1, 2, 5]. However, it also has disadvantages as well as advantages. The LBP algorithm causes smearing effect when the overlapping image occurs. This is due to the summation of the back projected signals for each pixel [1-4].

The implementation of LBP algorithm in Field Programmable Gate Array (FPGA) is one of the most challenging parts in optical tomography system. Time consuming to develop the project on FPGA causes many researchers did not used it for image reconstruction. Moreover, the difficulty in programming at Register Transfer Level (RTL) also makes the researcher do not used it [6]. Besides that, manual coding of HDL in programming can increase human error [7]. Therefore, Math Works provides an efficient method to program the FPGA. By using HDL coder, user can convert Matlab and Simulink block function to Hardware Description Language (HDL) without having trouble.

Here, the purpose of this study is to design and modeling LBP algorithm for FPGA application. Previously, LBP algorithm has been implemented on the microcontroller in optical tomography system. However, it's contributed many problems such as low capacity memory and slow data processing [8]. Therefore, an FPGA has been proposed to overcome this problem since it has big capacity memory and fast data processing. Altera DE2-115 has been proposed to be used for image reconstruction.

OVERVIEW OF THE MODELING DESIGN

In this project, LBP algorithm has been implemented in image reconstruction by using Matlab Simulink block. Visual Basic software has been used in order to generate the sensitivity map by developing virtual projection for each transmitter to receiver. The sensor loss value occurs whenever an object blocking the signal transmits by transmitter to receiver. Whilst, the summation of voltage distribution provide information of concentration profile [9]. The tomography image is display based on Equation. (1) where it shows the mathematical formula to reconstruct the image by using LBP algorithm [10].

$$V_{LBP} = \sum_{Tx=Rx=1}^{m} S_{Tx,Rx} \times \overline{M}_{Tx,Rx} \quad (1)$$

Where V_{LBP} is voltage distribution, $S_{Tx,Rx}$ is sensor loss value of transmitter and receiver and $\overline{M}_{Tx,Rx}$ is sensitivity maps of transmitter and receiver.

Figure-1 shows the flow to reconstruct tomogram image by using LBP algorithm. Firstly, the sensitivity maps must be processed for every path projection by defining its pixel location. All the elements in the sensitivity maps are summed up. Then, the pixel location of sensitivity map is divided with result obtained from the previous step. The result obtained is multiplied with the sensor loss and

maximum number of color pixel used. Then, the tomogram image is created.

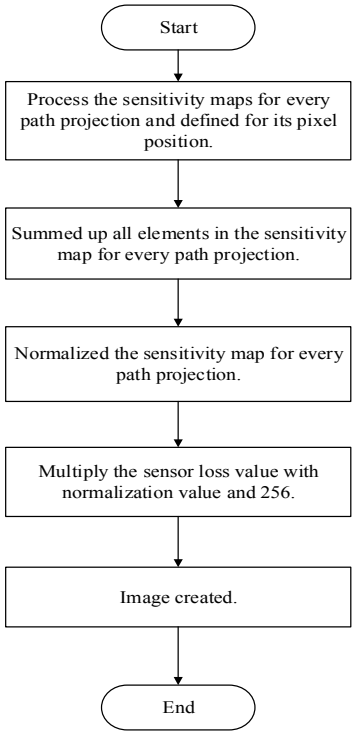

Figure-1. Flowchart of LBP algorithm.

Based on Figure-2, it shows how to design the LBP algorithm by using Matlab Simulink. There are two M-file function block has been used which are M Block and M1 Block. The M Block contained information about the sensitivity map for each subsystem. Meanwhile, M1 Block contained all sensitivity maps involved in optical tomography system. 64x64 matrix of sensitivity map is used in this project since it can produce a high quality image. Whilst, Matrix Sum Block is a mathematical operation where it will sum up all the elements of sensitivity map in M1 Block. Then, normalization step occurs when the sensitivity map in M Block is divided with summation elements in M1 Block. The result obtained is multiplied with sensor loss value and 256.

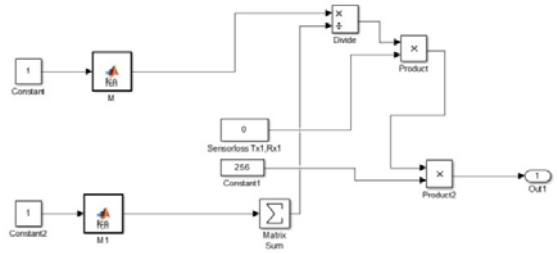

Figure-2. Block design for subsystem.

From Equation. (1), it shows that the voltage distribution is obtained from summation of multiplication between sensor loss and sensitivity map. Therefore, in Matlab Simulink the voltage distribution is obtained from summation of subsystem (Figure-2) in optical tomography system. This voltage distribution is converted to color pixel which produced the tomogram image. The overall design of LBP algorithm can be seen in Figure-3. In this project there are 40 subsystems involved to produce the tomogram image. Each subsystem has different sensitivity map and sensor loss value. The tomogram image is displayed by using Matrix Viewer Block.

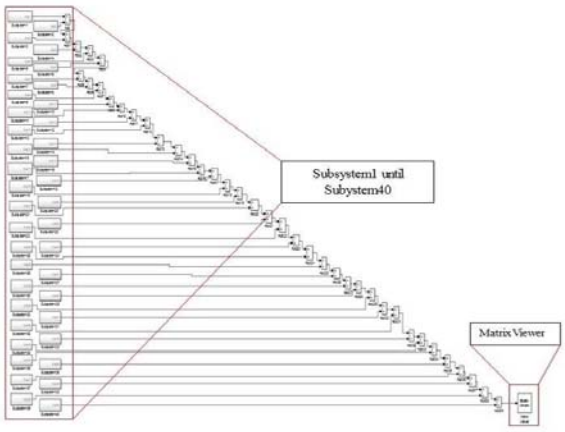

Figure-3. Design of LBP algorithm by using Matlab Simulink.

RESULT AND DISCUSSIONS

There are three conditions has been tested in this system. Firstly, the system has been tested when no object inside the pipe. Figure-4 shows the result obtained. Based on Figure-4, it shows the signal transmit by transmitter has been successfully received by the receiver. No sensor loss has occurred since no blockage the signal from the transmitter.

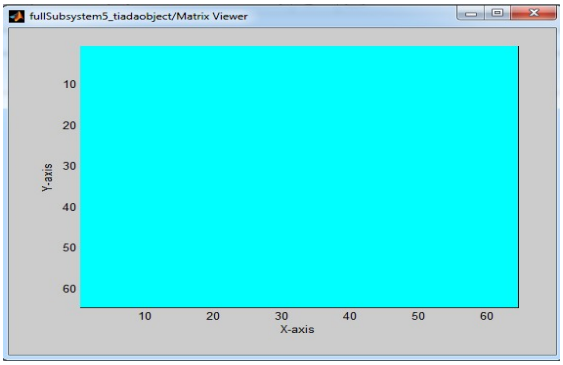

Figure-4. No object in the pipe.

For the second test, an object is placed in the pipe. Figure-5 shows an object is detected in the pipe. The object is blocking the signal transmit by Transmitter6 (Tx6) until Transmitter12 (Tx12) in horizontal axis from receiving the signal by Receiver6 (Rx6) until Receiver12 (Rx12). Whilst, in vertical axis Receiver26 (Rx26) until Receiver30 (Rx30)

are not receiving the signal transmit by Transmitter26 (Tx26) until Transmitter30 (Tx30).

For the last test, Object A and Object B are placed in the pipe. It can be seen in Figure-6. The Object A causes the signal transmit by Transmitter16 (Tx16) until Transmitter18 (Tx18) are not received by Receiver16 (Rx16) until Receiver18 (Rx18) in horizontal axis. Meanwhile, in vertical axis the Object A prevents the signal received by Receiver22 (Rx22) and Receiver23 (Rx23). At the same time, Object B is blocking Transmitter2 (Tx2) until Transmitter4 (Tx4) from transmitting the signal to Receiver2 (Rx2) until Receiver4 (Rx4) in horizontal axis. Whilst, in vertical axis Receiver35 (Rx35) and Receiver36 (Rx36) are not received signal transmit by Transmitter35 (Tx35) and Transmitter36 (Tx36).

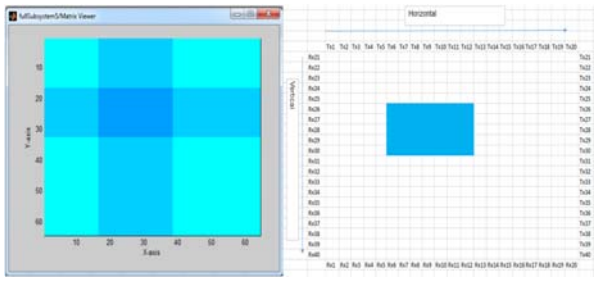

Figure-5. An object detected in the pipe.

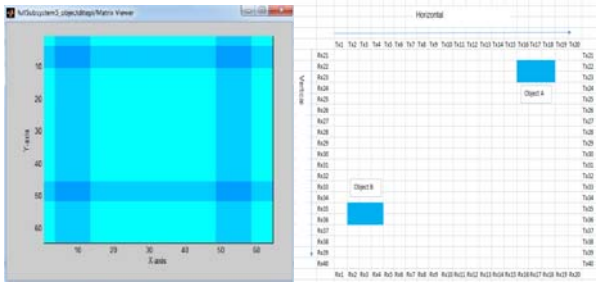

Figure-6. Two objects detected in the pipe.

CONCLUSIONS

In conclusion, the LBP algorithm has been successfully designed and modeling by using Matlab Simulink. It shows that the Matlab Simulink capable to display the tomogram image during no object in the pipe and during an object in the pipe. For future work, this design will be converted to HDL code by using HDL coder. The HDL coder provided by MathWorks enable user to use the HDL Workflow Advisor in order to convert the design to HDL code. Thus, the LBP algorithm can be implemented in FPGA.

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