

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 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 can 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.

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 tomography 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 compare to other algorithms. Moreover, it has become a popular method among researchers due to low computation, simple and fast response algorithm [1,2,5]. However, it also has disadvantages as well as advantages. The LBP algorithm can cause 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 algorithms 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 cause many researchers did not use it for image reconstruction. Moreover, the difficulty in programming at Register Transfer Level (RTL) also makes the researcher do not use it [6]. Beside that, manual coding of HDL in programming can increase human error [7]. Therefore, MathWorks 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, its 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. Commonly, 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 has been blocking the signal transmit by transmitter to receiver. Whilst, the summation of voltage distribution provide information of concentration profile [9]. The tomography image is display based on Eq.1 where it shows the mathematical formula to reconstruct the image by using LBP algorithm [10].

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

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

Fig.1 shows the flow to reconstruct the tomography 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 map 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 sensory loss and maximum number of color pixel used. Then, the tomography image is created.

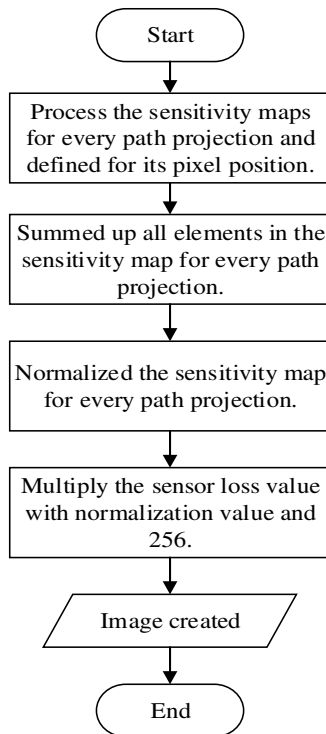


Fig.1: Flowchart of LBP

Based on Fig.2, it shows how to design the LBP algorithm by using Matlab Simulink. There are two M-file function block that 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 sharp image. Whilst, *Matrix Sum Block* is a mathematic 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.

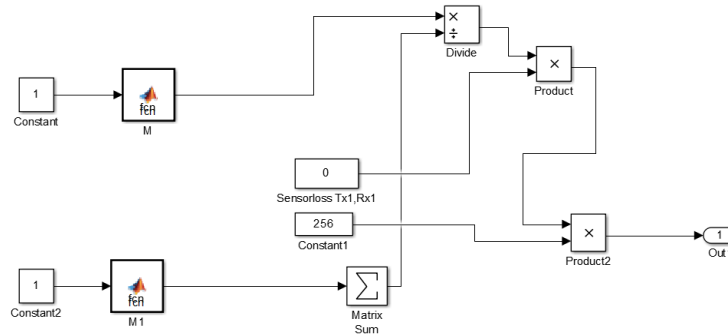


Fig.2: Block design for subsystem

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

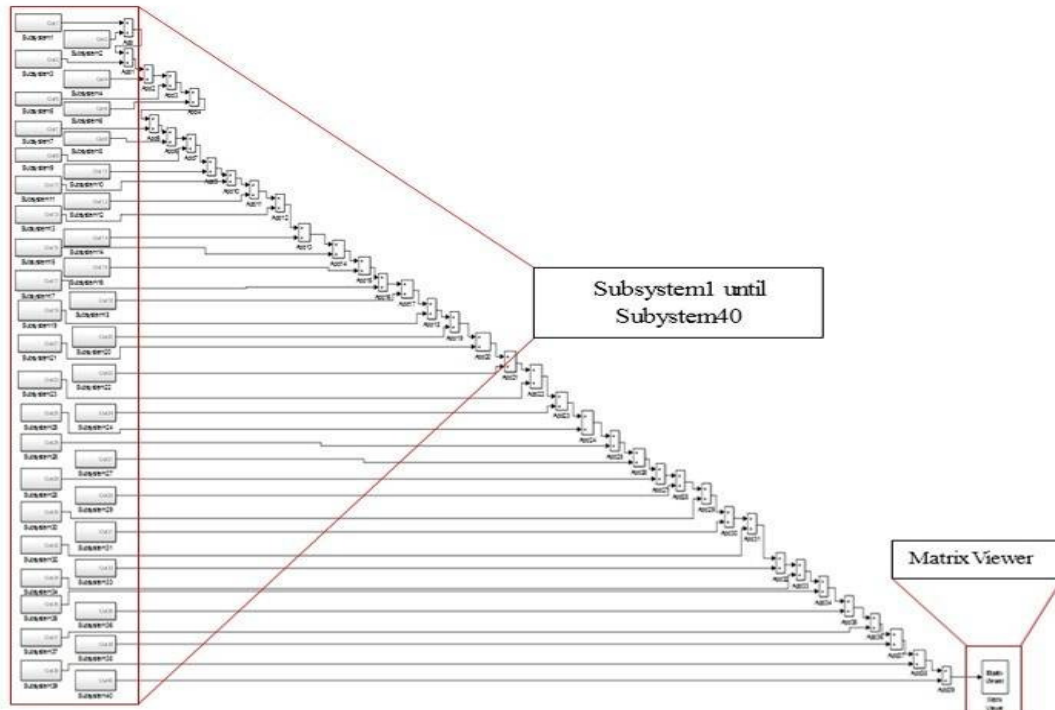


Fig.3: Design of LBP algorithm by using Matlab Simulink

Result and Discussion

There are three conditions has been tested in this system. Firstly, the system has been tested when no object inside the pipe. Fig.4 shows the result obtained. Based on Fig.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.

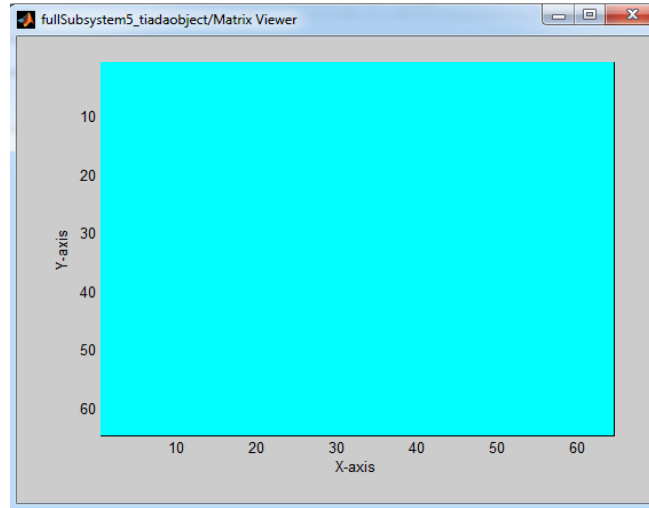


Fig.4 : No object in the pipe

In the second test, an object is placed in the pipe. Fig.5 shows an object is detected in the pipe. The object has been blocked 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)*.

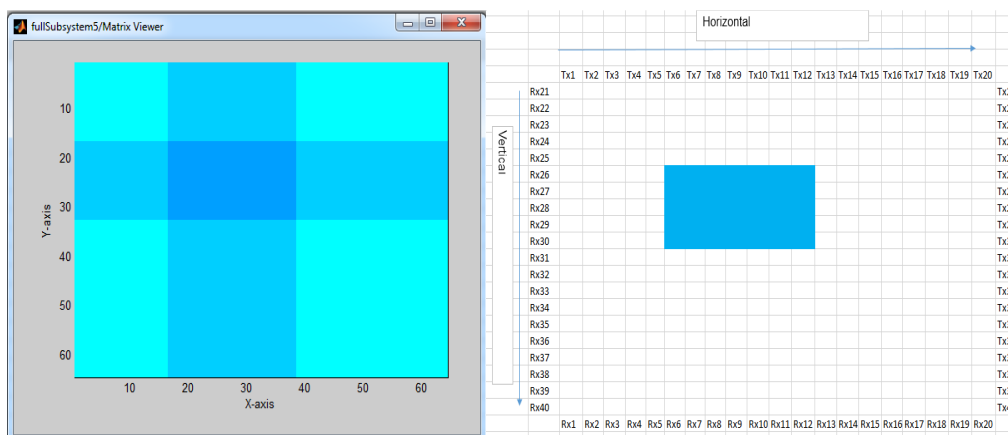


Fig.5: An object detected in the pipe

In the last test, *Object A* and *Object B* are placed in the pipe. It can be seen in Fig.6. The *Object A* causes the signal transmit by *Transmitter16 (Tx16)* until *Transmitter18 (Tx18)* is 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* has been blocked *Transmitter2 (Tx2)* until *Transmitter4 (Tx4)* from transmitting the signal to *Receiver2 (Rx2)* until *Receiver4 (Rx4)* in horizontal. Whilst, in the vertical axis, *Receiver35 (Rx35)* and *Receiver36 (Rx36)* are not received signal transmit by *Transmitter35 (Tx35)* and *Transmitter36 (Tx36)*.

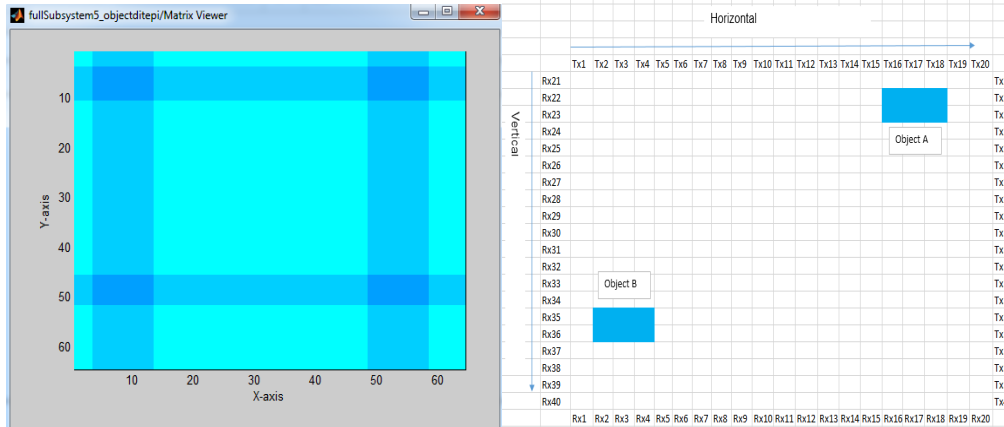


Fig.6: Two objects detected in the pipe

Conclusion

In conclusion, the LBP algorithm has been successfully designing and modeling by using Matlab Simulink. It shows that the Matlab Simulink capable to display the tomography 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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References

- [1] Y. Abdul Wahab., M.A. Ahmad., R. Abdul Rahim., and M.H. Fazalul Rahiman., Application of transmission-mode ultrasonic tomography to identify multiphase flow regime, Int. Conf on Electrical, Control and Computer Engineering, 2011.
- [2] S.W. Smith., The Scientist and Engineer's Guide to Digital Signal Processing, California Technical Pub, 1997.
- [3] J. Puspanathan et al., Edge detection algorithm for enhancement of Linear Back Projection tomographic images, Jurnal Teknologi, 2014.
- [4] S.Z.M. Muji., S. Sari., R. Abdul Rahim., and M.H.F. Rahiman., Optical tomography: a new filter technique for post processing image, IEEE Int. Conf on Control System, Computing and Engineering, 2012.
- [5] A. Rerkratn., K. Chitsakul., A. Soisup., and V. Wuti., Electrical capacitance tomography system for monitoring process flow in pipe, SICE Annual Conf, 2010.
- [6] Z. Que., Y. Zhu., X.Wang., J. Yu., T. Huang., Z. Zheng., L. Yang., F. Zhao., and Y. Fu., Implementing medical CT algorithms on stand-alone FPGA based systems using an efficient workflow with sysgen and Simulink, IEEE Int. Conf on Computer and Information Technology, 2010.
- [7] Y.P. Siwakoti., and G.E. Town., Design of FPGA-controlled power electronics and drives using matlab Simulink, IEEE ECCE Asia Downunder, 2013, pp. 571-577.

- [8] H.S. Murali., and M. Meenakshi., Design and development of FPGA based data acquisition system for process automation, Communications in Control Science and Engineering (CCSE), 2013, 1(1).
- [9] T.R. McKeen., and T.S. Pugsley, The influence of permittivity models on phatom images obtained from electrical capacitance tomography, Institute of Physics Publishing, 2002.
- [10]M.H. Fazalul Rahiman., R. Abdul Rahim., and H. Abdul Rahim., Image reconstruction algorithms for ultrasonic tomography, Jurnal Teknologi, 2011, vol 54.