Research On Real-time Processing System Of Hyper-spectral Image Based On FPGA

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Abstract. The real-time is an importance on judging the performance of the image processing system . The instantaneity means the system must have the reaction in the definitive time .In this research , the time in disposing an image must be limited in millisecond from receive the image to operate and report the information . So this customized image processing system should have the enough operation ability in hardware , combine the software and related algorithm to guarantee the real-time of the process .

Introduction

Most of the image process system can fulfill the real-time demand in low-resolution , but cannot fulfill in the high-resolution . Hyper-spectral image means high-resolution、high-bandwidth data , the processing speed is always nG bit/s, the traditional serial design cannot meet the requirement , the characteristic in parallel processing let FPGA provide new ways to solve this problem .

PCA

PCA as Principal Components Analysis , the principle theory is let the previous variable reconstitute to several unconcerned aggregative variable and wipe off fewer ones according the actual requirement at the same time , response the previous variable message as many as possible . This method can be used in dimensionality reduction and feature extraction .

Assume X is an m*n matrix and constitute by the sample data .m represent attribute dimension , n represent sample number . Throw linear transformation make X matrix into Y matrix , let the covariance matrix of Y to diagonal matrix , thus Y considered as the principle component of X .
The linear transformation formula from X to Y : Y = PX

Covariance of X and Y :$C_X = \frac{1}{n}XX^T C_Y = \frac{1}{n}YY^T$

The relation between $C_Y$and :C_X

$$C_Y = \frac{1}{n}YY^T$$

$$= \frac{1}{n}YY^T$$

$=\frac{1}{n}$ （PX）$(PX)^T$

$=P\ (\frac{1}{n}XX^T)P^T$

$$C_Y = PC_XP^T$$

$C_X$is symmetric matrix , so eigenvalue decomposition make X into diagonal matrix ,

$$C_Y = PC_XP^T$$

$= P\ (E^TDE)P^T$

$= (PP^{-1})\ D\ (PP^{-1})$

$C_Y = D$

Above the formula : $P = E^T$

D is diagonal matrix constitute by the eigenvector of C_X . P is linear narrative , every line of P is the diagonal matrix of C_X , and P is orthogonal matrix .

So , work out P can get the principal component matrix .

Above all there are about three steps to bring out the principal component of Hyper-spectral image :

1、minus the average value

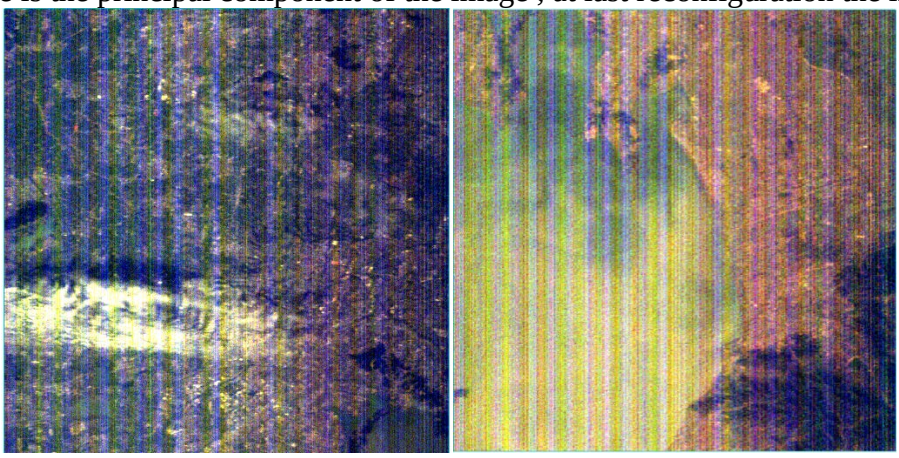
Work out the average value of all spectral coverage , minus the one of the original image .

2、work out the variance

Transform the three-dimensional image into two dimension (spatial dimension and spectrum dimension) , get a N*P matrix named I , work out the covariance of I , form a N*N matrix .

3、work out the eigenvalue of N*N matrix

The eigenvalue is the principal component of the image , at last reconfiguration the image .



The left image is not disposed , the right one is disposed . In the right one , it can recognize the lake and lakeshore obviously . So it have an impressive effect in using Matlab to analysis the principal component .

Use the System Generator as an instrument to generate Verilog code

1、System Generator can imaging modeling the hardware system in need , under the condition of Simulink the modeling number system can translate into FPGA project .It reduce the time of logic design and the hardware technological process , and lessen the probability of error .And use Sys-Gen to emulation the system can simplify the complex test-bench ; What's more , Sys-Gen hardware union simulation function can let the FPGA act as part of the system design , make the large-scale parallel computing which improved come true , and then can accelerate the simulation speed of other section .

Above all there are about five steps :

(1) Describe the arithmetic model with mathematical method

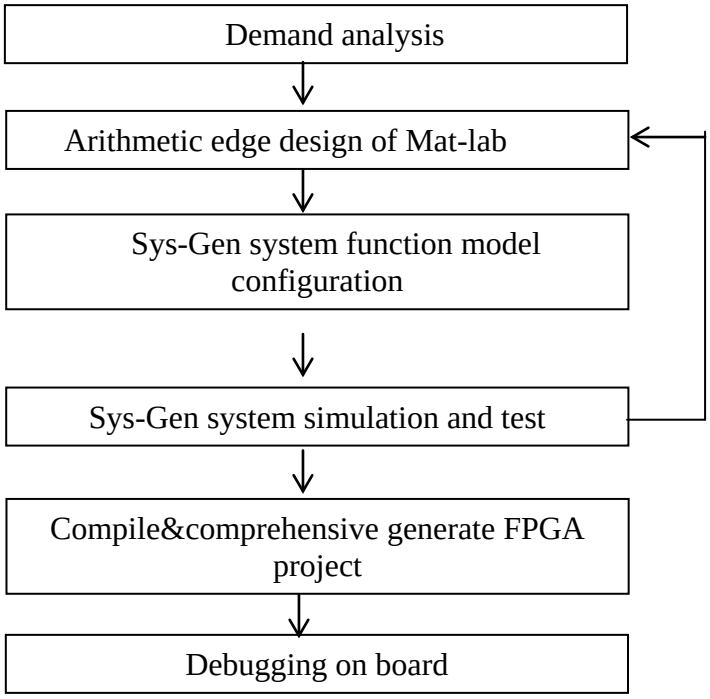
(2) Set up and simulate the system model , in the beginning use double precision

(3) Make the double precision arithmetic into fixed point

(4) Start System Generator , generate Verilog code and other files

(5) Simulate and debugging

2、System Generator ordinary model



The principal component analysis board of Hyper-spectral image

1、Software

As to the 1000fps image , the processing speed of hardware must be under millisecond level . So ,the logic design part of FPGA in the arithmetic , the write and read design of data flow can ensure the demand of real-time .

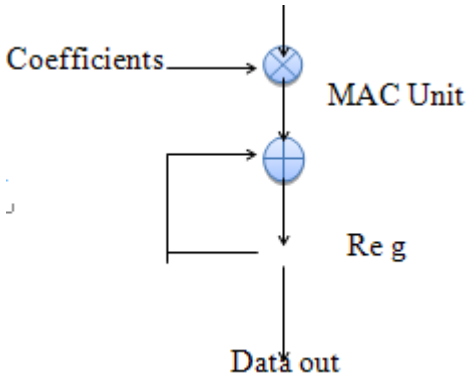
2、hardware

Because of the succession pattern of DSP , the speed of data processing is slow , and it lack the characteristic of real-time , which restrict the apply of DSP that high demand in speed and capacity .

FPGA constitute with a large number logic macro-cell that linked by switch network , internal logic cell and switch network are all programmable , throw the configuration these cell can form different hardware structure ,and achieve different function .

(1) The operating mode of DSP

Data In



256 loops needed

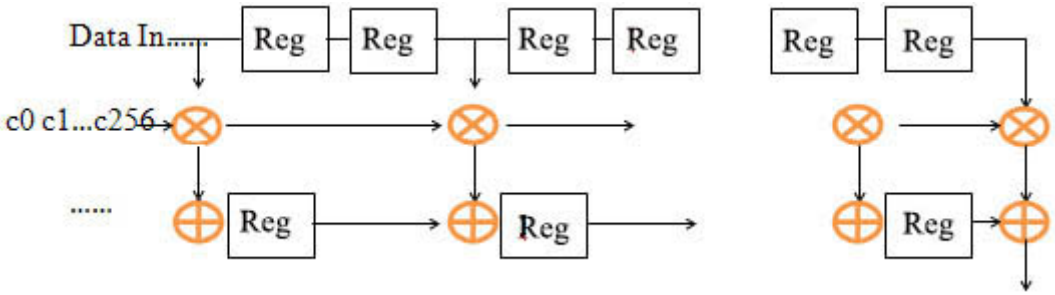
to process samples

For 1G data , 256 cycles , it can transmit 4M data in every cycle .

$$\frac{1\ GHz}{256\ clock\ cycles} = 4\ MSPS$$

(2) The pipeline model of FPGA

FPGA-based DSP – Parallelism

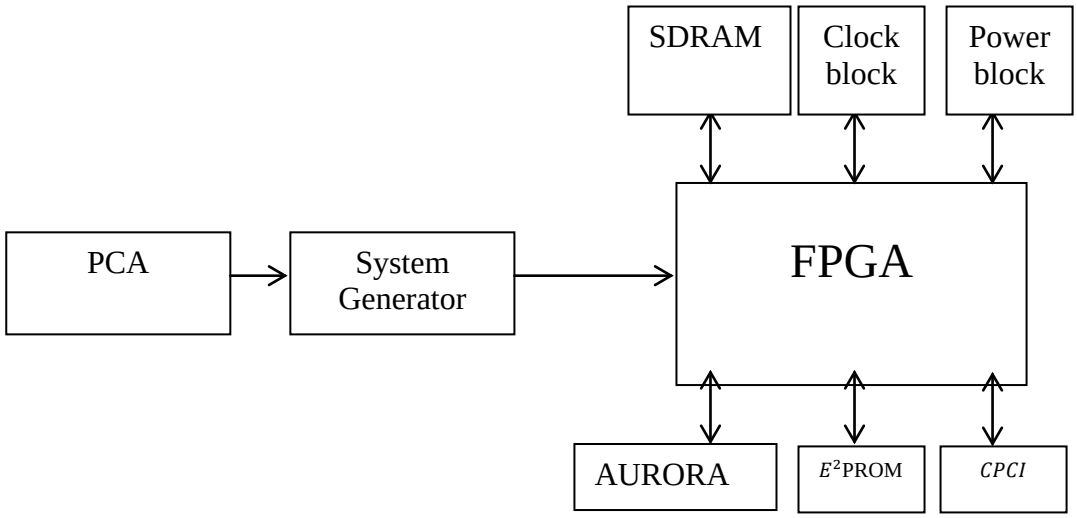


Data out

$$\frac{500MHz}{1 \text{ clock cycles}} = 500 \text{ MSPS}$$

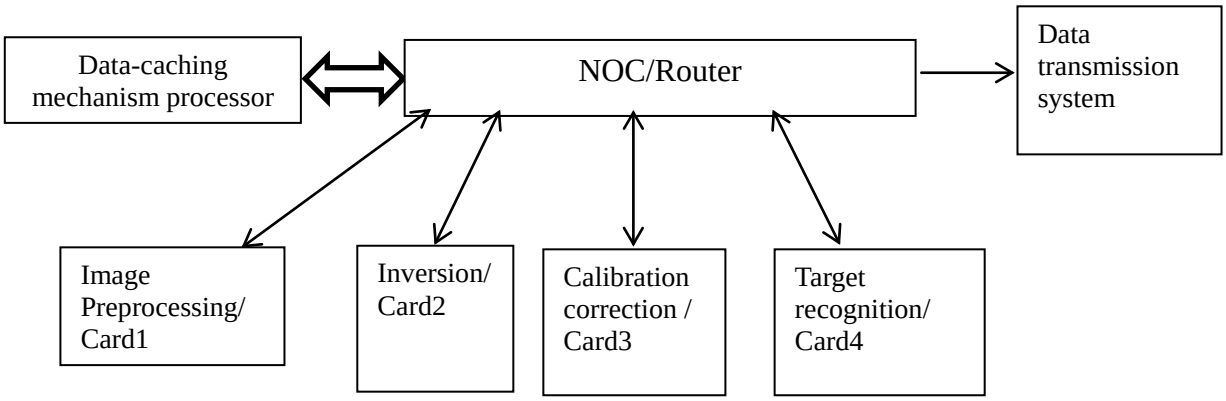
So , the transmit speed can reach 500MSPS in theory with the parallel processing of FPGA , which make the real-time transmit came true .

3、The block diagram of image processing



Spectral inversion processing card—time distribution of real-real processing model

Pipeline design of FPGA



Data volume of the original image : 4096*256*12bit*266fps = 3.35Gbps

Space between two frame : 266fps , equal to 3.76ms

Time distribution of the Spectral inversion processing card :

Core processing device of FPGA of every block , use the 125MHz clock and 5Gbps SRIO connector

By analysis , the time of full algorithm processing is 9.2ms :

Card	Image Preprocessing	Inversion	Calibration correction	Target recognition
time	1.8ms	3.5ms	2.9ms	1ms

According to the form , the time of the system will spend 3.5ms when use the pipeline work pattern .

Summary

In this paper ,work out the principal component analysis of Hyper-spectral image in the Mat-lab platform , and get the major message of the image with an impressive effect after processing . Graphical model the hardware system in need by System Generator , the modeling number system transform FPGA project under the Simulink condition , finish the transform from Mat-lab code to FPGA code . According the pipeline character of FPGA design the read and write of the data flow of the system to make sure the demand of real-time ,achieve live transmission of the Hyper-spectral image in the end .

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