CCSDS-MHC ON BEAGLEBONE-BLACK BOARD FOR LOSSLESS HYPERSPECTRAL IMAGE COMPRESSION

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ABSTRACT: This project is to achieve a lossless hyperspectral image compression of satellite imagery by implementation of Consultative Committee on Space Data Systems (CCSDS) algorithm named CCSDS Lossless Multispectral and Hyperspectral Image Compression (CCSDS-MHC) on Beaglebone-Black board (BB-Black). Hyperspectral image refers to the image which is represented by more than hundred number of narrow and contiguous spectral bands. In our case it is 224 and 196 spectral bands for AVIRIS and Hyperion respectively. Image compression applied to reduce storage requirements and improve transfer speed over the standard connection. Because of the large number of bands, the on-board memory required is huge. Lossless compressor that exploits inter band correlations is desired. A BeagleBone-Black board is used to implements and optimizes the CCSDS Lossless Multispectral and Hyperspectral Image Compression (CCSDS-MHC) algorithm. As for the result, the ratio for Beaglebone-Black board execution time compared to Desktop is in the range of 10 to 25 times longer. The losslessness is verified by referring to the Desktop program. The compression ratio is in the range of 2.0 to 5.0.

KEYWORDS: *CCSDS-MHC Algorithm; Image Compression; Beaglebone-black; Hyperspectral Image; Lossless Compression*

INTRODUCTION

Hyperspectral imaging is a technology that has been used to study planetary surfaces in form of satellite imagery. "Hyperspectral cameras (or imaging spectrometers) have a high spatial resolution (~1–30m) coupled with regular sampling (every ~4–15nm) of a broad spectral range, which can cover wavelengths ranging from ultraviolet (~0.35µm) to thermal infrared (~12µm)" (Ceamanos & Valero, 2016). Hyperspectral image represents image with hundreds number of contiguous spectral bands. Images produced by hyperspectral sensor contain more data than multispectral sensor images hence make it much more favorable for data interpretation. Hyperspectral system initially samples the light, then it passes through a slit then disperses it (Metkar & Kamalapur, 2018).

AVIRIS image is a hyperspectral image captured by using diffraction gratings for band separation with two sets of CCD arrays. One of the array is to sense in the visible range and the other for wavelengths in the Near-IR to Short-Wave-IR range. AVIRIS has 224 contiguous spectral channels, extending wavelength over a range of 0.38 to 2.50 µm. Hyperion is a hyperspectral instrument that can capture high resolution images of the earth surface in 242 contiguous bands but out of 242 bands, only 196 bands have been extracted and used in this project.

Because of the amount of data that need to be stored and transferred is large, on-board compression of the images becomes an important action to be taken and performed for optimal usage of on-board storage and downlink speed. The data compression in on-board Hyperspectral Imaging processing is performed to lower the amount of data for transmission back to earth. Lossless image compression is desired to make sure that the image data is remain the same throughout the whole transmission process.

Another objective for this project is to measure and compare the performance of the algorithm in terms of compression speed with the other implementation platform (Desktop). Previously, there are many other implementation of this algorithm but to our knowledge, none of them try Beaglebone-Black board yet.

CCSDS-MHC ALGORITHM

The Consultative Committee for Space Data System (CCSDS) released the image compression recommended standard that specifies a method for lossless compression for hyperspectral image data and a format for storing the compressed data known as CCSDS-MHC. It is one of predictive coding type algorithm which means that it encodes the difference between the data derived from past data and actual data. Figure 1 shows the CCSDS-MHC algorithm block diagram. Basically, it consists of two main parts or processes which as predictor and encoder.

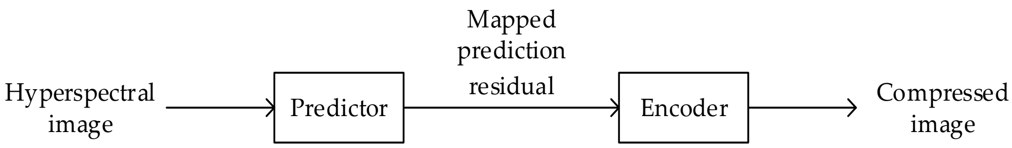

Figure 1 CCSDS-MHC algorithm block diagram.

Predictor part specifies the calculation of the predicted sample values from the input image sample and come out with the mapped prediction residuals. The mapped prediction residuals will then be fed into the encoder part. The encoder part specifies the encoding process and the format for the compressed image.

Predictor's process: A local sum ($\sigma_{z,y,x}$) of the neighboring samples of the current sample ($s_{z,y,x}$) in the current band is computed based on user choice either neighbor-oriented or column-oriented sum. the local differences vector $U_{z,y,x}$ is calculated by referring to the previous local sum value. Full prediction mode algorithm needs central ($d_{z,y,x}$) and directional ($dN_{z,y,x,}$ $dW_{z,y,x}$ and $dNW_{z,y,x}$) local differences values. Next, the predicted sample values ($\hat{s}_{z,y,x}$) is obtained by performing the dot product between the local differences vector $U_{z,y,x}$ and a weight vector $W_{z,y,x}$ that is updated according to the resulting prediction error (i.e., the difference between prediction and actual sample). Lastly, the prediction residuals are mapped to positive integer values $\delta_{z,y,x}$ (Rodríguez, Santos, Sarmiento, & Torre, 2019).

A compressed image consists of a variable-length header which encodes image and compression parameters and also a body, which is consists of losslessly encoded mapped prediction residuals from the predictor part of the algorithm (Consultative Committee for Space Data Systems, 2012).

BEAGLEBONE-BLACK BOARD

Beaglebone-Black is designed for use as an embedded system-kind of computer system designed mainly to perform some tasks such as control, store and process the data. A small, standalone Linux computer is another word to represent this board. This board is designed with low cost ARM Cortex-A8 based processor. Version of the board that was used in this project is Revision C (Rev C). It is an improved and the latest version of Beaglebone-Black. Some updates and modifications were made from time to time.

RESEARCH FLOW

This project is focusing on the compression part of the algorithm which consists of the predictor and encoder part. But the decompression part is also be in consideration due to the losslessness verification stage. The decompression part is just applied during Desktop's implementation because of not enough amount of memory available on the Beaglebone-Black board. Figure 2 shows the overall program block diagram that was written in Eclipse software. The output from the compression will be stored in term of binary image file. Specifically, for Desktop version, this file will then be accessed for the decompression part of the algorithm. The output will be compared to the original image to verify the losslessness of this program.

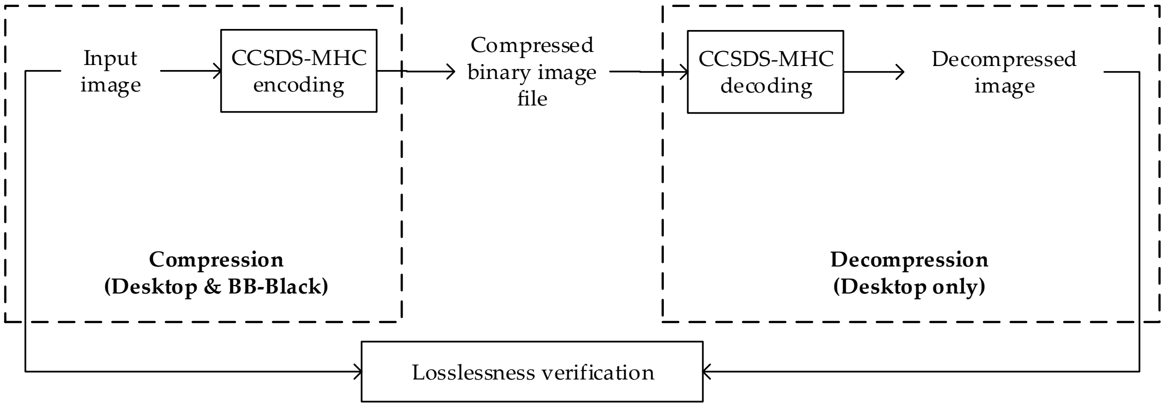

Figure 2 Overall program block diagram.

EXPERIMENTAL RESULT

The algorithm is implemented on both platforms, Desktop and Beaglebone-Black board. The execution time is recorded for both platforms. Compression ratio between original image and compressed image is also recorded. Table 1 shows the result collected from both platforms.

Table 1 Result from Desktop and BeagleBone-Black board.

	Hyperspectral Image	Abbreviations	Execution time (sec)		Comp. Ratio (CR)
			Desktop	BB-Black board	
AVIRIS (512×512×224)	Jasper Ridge Scene 1	jasper1	49.3466	491.7597	3.2439
	Low Altitude Scene 1	low1	41.1577	496.0939	2.9894
	Low Altitude Scene 5	low5	40.6982	488.8962	2.9963
	Lunar Lake Scene 1	lunar1	39.1474	492.7439	3.2206
	Yellowstone Calibrated Scene 0	YellowstoneCal0	36.5719	490.9534	4.0982
	Yellowstone Calibrated Scene 10	YellowstoneCal10	38.1957	498.5600	4.8597
	Yellowstone Calibrated Scene 11	YellowstoneCal11	38.3624	497.4486	4.4667
	Yellowstone Calibrated Scene 18	YellowstoneCal18	37.4506	499.5036	4.0071
Hyperion (256×256×196)	EO1H1660512002107110PZ_SGS_01	Atturbah	5.6049	148.5067	2.4858
	EO1H1700782002055110PY_SGS_01	Benoni	6.3215	148.5610	2.4601
	EO1H0120312001129111P1_PF1_01	Boston	6.3598	148.7136	2.0029
	EO1H0920842002053110PY_AGS_01	Coolamon	6.4928	148.5187	2.4740
	EO1H0910822002071110KW_AGS_01	Dubbo1	6.4183	148.5269	2.4751
	EO1H0140362001127110PP_AGS_01	Edenton	6.4645	148.6529	1.9990
	EO1H0090112001140111PP_PF1_01	Greenland	7.0326	148.5518	2.3501
	EO1H1370392002032110PZ_SGS_01	Maizhokunggar	6.7550	148.5707	2.4824
	EO1H1090232002092110PZ_AKS_01	Okha	6.5950	148.5655	2.4558
	EO1H0150332001134111P1_AGS_01	Portobago	6.8863	148.6124	2.4729

From the result of the execution time for both AVIRIS and Hyperion image for Desktop, the time taken is considered fast compared to Beaglebone-Black board platform. Execution time is faster for Hyperion images compared to AVIRIS images for both platforms due to the image size which is 512 rows × 512 columns × 224 bands for AVIRIS and 256 rows × 256 columns × 196 bands for Hyperion.

Desktop program only take less than one minute to complete the compression stage for AVIRIS images and even faster for Hyperion images which is less than 10 seconds. Meanwhile, Beaglebone-Black program took about eight minutes to complete the compression part for AVIRIS images and about three minutes for Hyperion images. For the losslessness verification stage (Desktop platform), it is verified that for all the input images used, the compression was lossless.

Even though the Beaglebone-Black program did not include the decompression and losslessness verification stages, it is verified by referring to the Desktop program since the program written was the same. The compression ratio for the Desktop program is similar to the Beaglebone-Black program. This is an indicator that the program that was written is the same for both platforms.

CONCLUSION

The execution time for Beaglebone-Black board is slower compared to Desktop. The ratio is in the range of 10 to 25 times longer than the execution time for Desktop. The advantages of using Beaglebone-Black board is that it is a low complexity and low power stand-alone computer. Even though the time taken is slower, it still worth a study since it will benefit the on-board compression application in terms of low cost and low power platform. The losslessness of the compression algorithm is verified by referring to the Desktop program. The compression ratio is in the range of 2.0 to 5.0 and similar for both platforms.

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