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Research paper

Data Compression with High Peak Signal to Noise Ratio Using Bisectional Cylindrical Wavelet Transform For a Satellite Image

K.Pranitha[1]*, Dr.G.Kavya[2]

* *Full Time Research Scholar, DepartmentofElectronicsandCommunicationEngineering, S.A Engineering College, Chennai -77, Professor, DepartmentofElectronicsandCommunicationEngineering, S.A Engineering College, Chennai-77*
**Corresponding author E-mail: pranithakarthik@gmail.com*

Abstract

Satellite imaging is an energetic way for the analyst to review about the space information, geoscience and space report analysis. Image compression is an essential specification which provides the actual information in transmitted data on earth observation satellites. It takes advantage to reduce the capacity of space info with a unique term intention to lower the memory capacity for intelligence accumulation, moderating, data deportation content modification considering performance transition. Image compression, it helps to obtain the original image file with deficient recognition capacity. Degradation in the content of an image file confesses enhanced images which are directed towards particular storage recognition. Image compression downgrades the content of an image file without depressing the original quality. In this paper, for satellite image compression, existing wavelet transforms like continuous wavelet transform (CWT), stationary wavelet transform (SWT), data compression using 2D wavelet analysis and the proposed method Bisectional cylindrical wavelet transform (BCWT) are performed and compared with the appropriate results. Performance parameters like Peak Signal to Noise Ratio, Signal to Noise Ratio, Maximum Absolute Error, Mean Square Error, Compression Ratio, Bits per Pixel and threshold value are evaluated and tabulated.

Keywords: *CWT; SWT; Data compression; 2D wavelet; BCWT.*

1. Introduction

Satellite images get depraved by reason of channel distortion and inaccurate space environment at the time of transference. It consists of extensive volume of data and that increases the magnitude of image; as a result it requires higher time for transmitting. Image compression may be lossy or lossless. Lossless compression is elected for factual determination and repeatedly for medicinal visualize, professional designs and clipart‘s. Lossy compression processed at less bit rates, suggests compression antiquity. Lossy methods are exclusively applicable for original images for instance like photographs in utilizations where lesser fall of integrity is adoptable to accomplish a consequential decrease in bit rate. Lossy compression’s outcome contains imperceptible variations which are optically known as lossless. Wavelet transform provides efficient image quality at high compression ratio and the importance of wavelets in image compression is, multiresolution levels of images. At each level, wavelet will save the differences (residuals) between the images at present level and the expected image from next level. Reconstruction of images is made by adding up of residuals in each level. The main advantage is residuals are easy to store. Previous works done in this area has been discussed herein.

2. State of the art

Satellite multispectral image compression method (Ahmed Hagag et al., 2017) based on removing sub bands to decrease the storage size of multispectral images with high quality resolution. Here discrete wavelet transform with entropy coder are adopted to perform compression process. By using this technique, image quality obtained by 3-11 db. Enhanced Thematic Mapper plus based satellite multispectral images are used to perform validation for the above compression technique. Binary tree coding with adaptive (BTCA) scanning order (Ke-Kun huang et al., 2017) is another algorithm to provide compression with low complexity. BTCA acquires large memory space but in this paper, a new coding technique BTCA with optimum truncation is used. According to BTCA with optimum truncation, images are divided into several blocks which are encoded individually. It will prefer the accurate truncation points for several blocks to sharpen the proportion of exaggeration at high compression Ratio with less memory space. Remote sensing image data is large in size so that it requires compression with low-complexity algorithm which can be used for space-borne equipment. This method is simple and fast which is suitable for space borne equipment. It improves PSNR as well as image visual quality. Wavelet transform followed by adaptive scanning method (S. Haddad et al., 2017) is preferred for a remote sensing image which is suitable for the on board compression. Wavelet transform is used to reduce the storage size and adaptive scanning method concentrates on protecting the texture information of a particular image. This combination of techniques improves the coding performance. Here entropy coding or any other complicated components are not used. Multiple Transmission Optimizations (Nan Jiang et al., 2017) is mainly used in telehealth applications especially adopted for medical images. It analyses the observed Complacent of the numerous medical images depends upon the lineament of Mobile Transmission Systems. In Multiple Transmission Optimization, set of transmittal images are correlated according to the pixel resolution and are organized into arrays based on optic resemblance. After performing Multiple Transmission Optimization, images are reconstructed and displayed for the different users. Interpolation based Adaptive lifting DWT with Modified SPIHT algorithm (Karim M.Nasr and Maria G. Martini 2017) In general; DWT is adopted for fast computation and low memory requirement. But it doesn‘t concentrate on region information. It provides both geometric and spatial information which concentrate on texture information. But new technique Interpolation based Adaptive lifting DWT more concentrates on image texture features and Modified SPIHT algorithm improves scanning process, reduces code bit length and run time.

Clustering based compression (Wei – Yen Hsu 2017) is adopted for the telemedicine applications and to improve the transference percentage, arcade scope and contact among medicinal team and outpatients. This method includes Competitive Hopfield neural network and Modified block truncation coding. Competitive Hopfield neural network is to bring out better clustering accuracy and to beaten the defects in oscillating basic rates of clustering.

Modified block truncation coding is to analyse the clustering regions with contrast compression ratio and to secure relevant image virtue data in case of small size images. This method is also recommended for the purpose of remote future responsibility coupled to cloud databases. In Joint Watermarking Compression scheme (Bouslimi D et al., 2016) there is a possibility to shadow the images or to justify their reliability exactly from their compressed bit stream. It concentrates on embedded capacity and distortion.

A watermarked image does not differ from their original visual which offers large capacity to provide support for various security services. This scheme is further extended for verifying the image integrity and authenticity. Visual Quality Evaluation Method (Karim M.Nasr and Maria G. Martini 2016) for Telemedicine Applications, a recent way for evaluating image quality and video quality. It investigate the trait of perceive decreased size logo encapsulated in an idle section of medical ultrasound frame.

This method concentrates on three different metrics, peak signal to noise ratio, structure similarity index metric, differential mean opinion score and it does not need the initial stage to evaluate the aspect; it acquires huge correspondence for the different metrics used. It also improves the quality between derived logo and the original frame. It results in compressed logo data with its overhead protection.

FPGA based communication stack (David selean et al., 2015) is used on Nano satellite space missions. This method permits the satellite operator to interact with satellite using CCSDS compliant RF link for the efficient communication. It is used for both space ground and on board communications. Here the Nano satellite is incorporate with ground station provisions. Here the method is constructed with less appliance usage so it diverts most of the limited usage resources towards endeavors.

A novel segmentation-based compression scheme (Wei – Yen Hsu 2015) used for telecommunication in telemedicine applications. The main objective of this method is to upgrade the knowledge displacement and conversation between patients and medicinal workers. This method includes watershed transform along with vector quantization. Watershed transform will sector an image into different domains to manage valuable estimation and designation.

Modified vector quantization is to inspect the sliced regions with distinct compression rates allowing sustaining necessary lineaments and depressing the image size. Wavelets are major generic method to perform and evaluate multiresolution images. It could also be utilized for one dimensional signal. It is appropriate and effective for image compression, removing noise and for image fusion. It impersonates the scale of lineaments in an image in addition to their topography. An elaborate Literature survey on various compression techniques (K.Pranitha and Dr.G.Kavya 2018) has been done. Figure 2.1 represents block diagram of wavelet method,

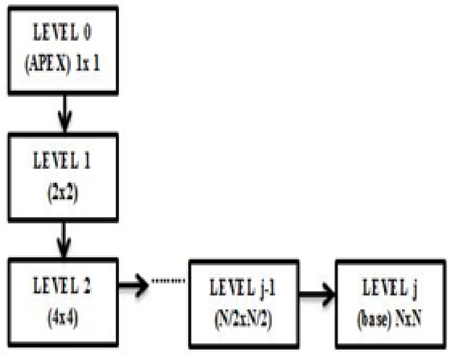


Figure 2.1: represents block diagram of wavelet method

Bisectional Cylindrical wavelet transform is proposed by considering the third level of compression i.e. Level 3 compressed image and the results of CWT, SWT, Data compression using 2D wavelet analysis and BCWT are compared and discussed in the below section.

Earth observation satellite image as shown in Figure 3.1 is used as an input image and the corresponding simulated results are obtained using MATLAB TOOL. Standard parameters PSNR, SNR, MAE, MSE, CR, BPP and threshold value are calculated for different compression techniques.

This paper is organized as follows, section 3 gives Need for satellite image compression, section 4 provide Comparison of image compression methods and the proposed BCWT, section 5 presents performance analysis using BCWT with other wavelet transforms and finally conclusions are given in section 6.

3. Need for an efficient approach of compression of earth observation satellite

Need for an efficient approach of compression of images is usually growing as raw images require immense volume of disk capacity which is assumed to be substantial disadvantage at the time of transmission and storage. Image compression applied to satellite images, to decrease their expenditure for storage or transmittal. Image compression algorithm proceeds with the preference of optic viewpoint and the demographic proprietary of image data to accommodate remarkable solutions related with wide compression techniques. The major intent of image compression is to contribute best image quality at a given compression rate or bit rate. The proposed method Bisectional Cylindrical Wavelet Transform which provides efficient level of compression (Level 3 compression).

4. Comparison Image Compression Methods

4.1. Continuous Wavelet Transform (CWT)

Continuous wavelets transform partitions continuous time action into wavelets. CWT retains capacity to compose time frequency illustration of a signal which isolates time and frequency region. The equation of continuous wavelet transform of a function x (t) can be shown in Equation (1) as,

$$X_W(a, b) = 1/|a|^{1/2} \int_{-\alpha}^{\alpha} x(t)\, \bar{\Psi}(t\text{-}b/a)\, dt \qquad (1)$$

To bring out the subsequent wavelets that can be transliterated and proportion of initial Ψ (t) is a time and frequency domain function for CWT called initial wavelets. It indicates application of composite associate. The scope of CWT is to produce origin activity wavelets. The inverse form of CWT can be expressed in Equation (2) as,

$$X(t) = C_\Psi^{-1} \int_\alpha^\alpha \int_\alpha^\alpha Xw(a, b)\, 1/|a|^{1/2}\, \Psi^{-}(t\text{-}b/a)\, db\, da/a^2 \qquad (2)$$

$\Psi^{-}(t)$ is the dual function of Ψ (t)

4.2. Mexican Hat and Cauchy Wavelet Transform (CWT)

This method is a peculiar one of continuous wavelets system acknowledged as Hermitian wavelets. It has an expert tendency in estimating electrodynamics and also named as Marr wavelet. The wavelet equation can be shown in Equation (3) as,

$$\Psi(t) = 2/\sqrt{3}\sigma\Pi^{1/4}(1\text{-}(t/\sigma)^2)\, e^{-t2/2\sigma2} \qquad (3)$$

This wavelet is proximate by Gaussian behavior and it recovers appreciable estimation duration in two or three dimensionality. In generic, Cauchy wavelets are preowned to determine the comprehensive centrality of an object. These wavelets are preowned while centrality and location are compatible. There is no effort to constitute fivefold or tenfold centrality to create a particular shape. The centrality equation can be shown in Equation (4) as,

$$C \equiv C(0, \alpha, \beta),\ \{k^{-} \in IR^2 \mid \alpha < \Phi < \beta\} \qquad (4)$$

By using this technique, satellite image can be observed by the level upto maximum angle. Here three angles like initial middle and final level of angles are considered and the compressed output image is represented in Figure 4.2, Figure 4.3 & Figure 4.4. For initial angle _0‘ radians taken,
for middle and final _5pi/8 and 15pi/8‘ radians are taken

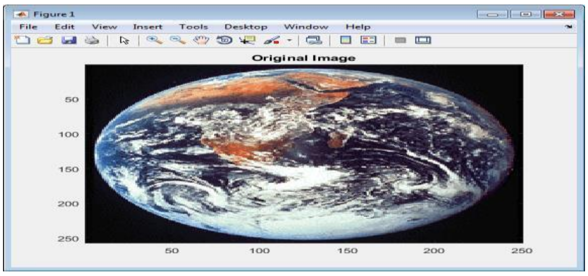


Figure 4.1 Input Image of Earth Observation Satellite

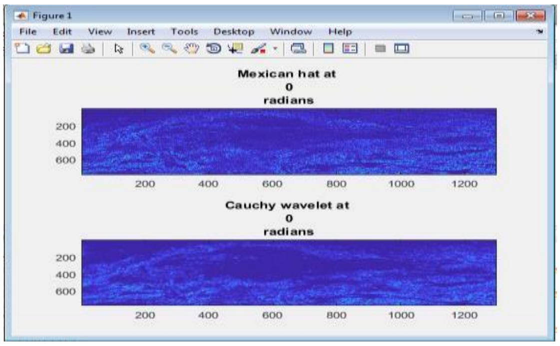


Figure 4.2 Mexican hat and Cauchy wavelet transform forangle _0 radians‘

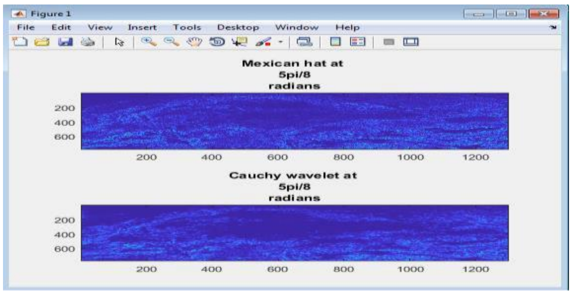


Figure 4.3 Mexican hat and Cauchy wavelet transform forangle _5pi/8 radians‘

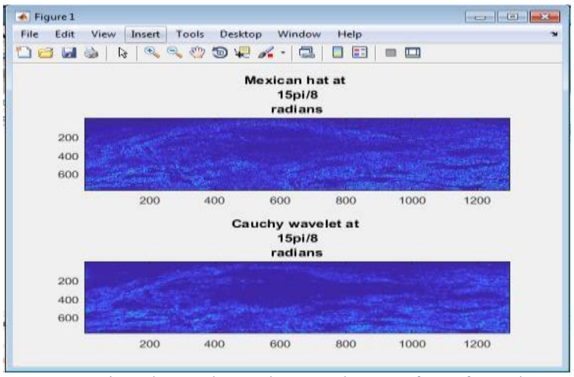


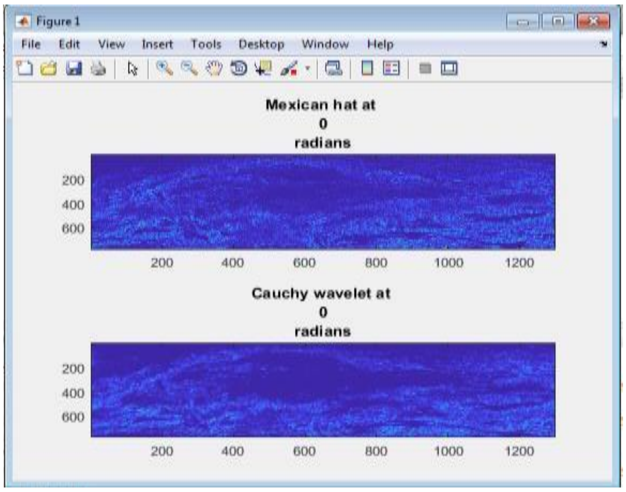
Figure 4.4 Mexican hat and Cauchy wavelet transform forangle _15pi/8 radians‘

4.3. Morlet Wavelet Transform

In this transform, compressed satellite image can be represented with scale index, angle index, and modulus, real and imaginary part. This method conferred endeavor an innate extension between frequency and time report which could resolve perception of convoluted value obtained as shown in Figure 4.5. It is not contracted as a restoration for Fourier transform, on the other hand comparatively allows conditional approach to time associated revision and has an benefit of numerous dimensions applicable in complementary deterioration analysis. The Morlet equation could be expressed in Equ (5) as,

$$\Psi(t)=C\sigma\Pi^{-1/4}\, e^{-1/2t2}\, (e^{i\sigma t} - k\sigma),\ k\sigma = e^{-1/2\sigma2} \qquad (5)$$

Main application of this method is preowned in medical field. Used to determine the uncommon changes in heart beat represented in (ECG) signal. In view of alteration in heart beat is a non-stationary signal which is applicable for wavelet based analysis.



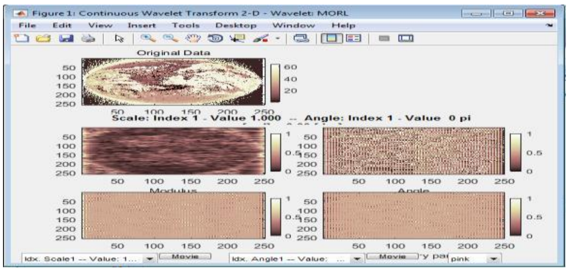


Figure 4.5 Morlet wavelet Transform for scale and angleindex

Stationary Wavelet Transform (SWT)

Stationary wavelet transform is an intrinsically efficient plan to obtain N levels. Each level contains compatible numeral of patterns. The repetition of N takes place in the wavelet domain to obtain coefficients. Figure 4.6 represents Digital application of SWT,

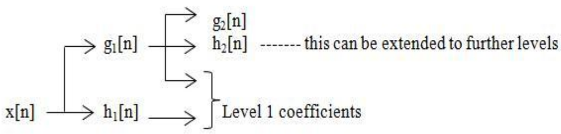


Figure 4.6: Digital representation of SWT

Figure 4.7 represents level1 approximation coefficients. After extending to further levels, level2 coefficients are obtained. In level2 image quality will be very low, which is represented **in Figure 4.8**. It is also called as uniform correction of DWT which do not affect the coefficients at each conversion level. Transliteration – invariance is accomplished by discarding down samplers and up samplers. Output of each level of SWT consists of equivalent number of samples as the input. For a decomposition of 'N' levels, there will be repetition of N in the wavelet coefficients. **Equation (6) & Equation (7)represent** SWT filter equation,

$g_i[n] \quad n_2 \quad g_{i+1}[n]$ (6)

$h_i[n] \quad n_2 \quad h_{i+1}[n]$ (7)

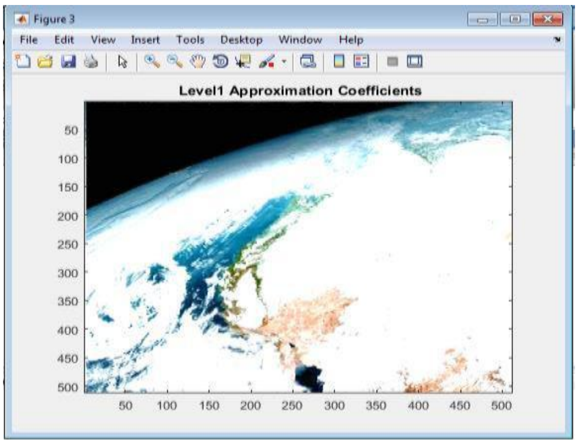


Figure 4.7 Level1 Approximation coefficients using SWT

Level 1 pixel values

512	512	3	4
512	512	3	4
512	512	3	4
512	512	3	4 and Maximum difference = 0

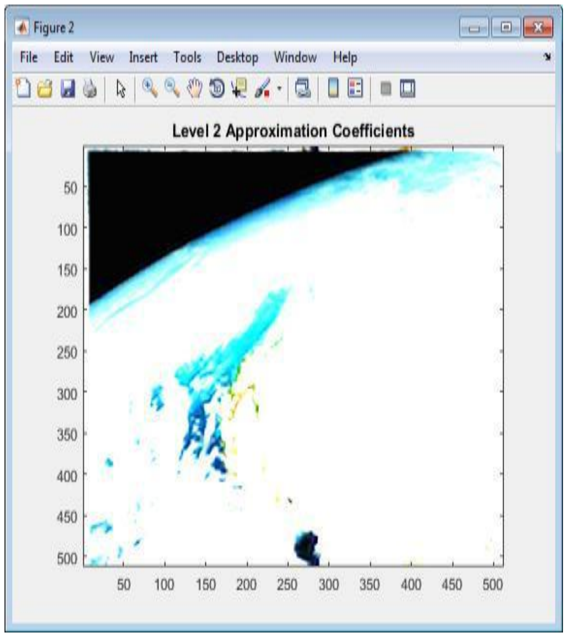


Figure 4.8 Level2 Approximation coefficients using SWT

Level 2 pixel values

512	512	3
512	512	3
512	512	3
512	512	3
512	512	3and Maximum difference = 0

Data Compression Using 2D Wavelet Analysis

Compression is one of the ultimate foremost relevance of wavelets. To compress an image using two-dimensional wavelet analysis, it includes three steps

- Decomposition: Adopt a wavelet; prefer level N. Enumerate the wavelet decay of signal at N level.
- Threshold value: Considering separate level in distinction to 1 to N, a point of inception is elected and hard thresholding is enforced to the schedule concentus.
- Reconstruction: Enumerate wavelet reformation applying the primary similar co-efficients of level N and the altered disclosed co-efficients of levels in distinction to 1 to N.

Effective compression accessions are feasible in this method

- The primary access can be expressed by catching the wavelet extension of the signal includes preserving the greatest complete rate co-efficients.
- Here global threshold, compression performance values are adopted so only one criterion must be selected.
- The secondary access can be found in implementing optically equivalent subordinate thresholds or point of inception.

Method 1- Level1-Dependent Thresholding

The compression appearance of an inclined wavelet substructures are generally coupled to the reliant insufficiency of the wavelet region sample of the signal. The concept in the background compression is placed on the statement that the formal signal part could be exactly approximated adopting ensuing factors; a) limited count of nearness co-efficients b) part of schedule co-efficients.

In this approach, the WDENCMP function percolates compression techniques in distinction to wavelet decomposition arrangement [c, l] of the image as shown in Figure 4.9

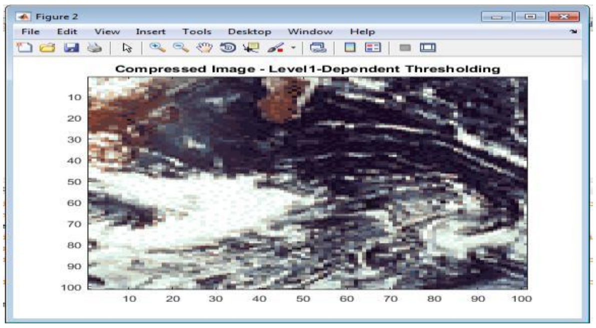


Figure 4.9 Level1 compressed image for Data Compressionusing 2D Wavelet Analysis

Level1 coefficient and density values

Perf0 = 80.9511
Perf02 = 79.2812
Cxd_density (compression density) = 0.190

Method 2 - Level2-Dependent Thresholding

The WDENCMP function confesses level as well as assimilation indigent thresholds. Here the resemblance is stored. Assimilated indigent thresholds are in three directions horizontal, diagonal and vertical. WDENCMP function starts compression technique from the image x.
Through level-dependent thresholding, the compactness of the wavelet dissolution was decreased by 3% during bettering the L2-stage readjusted by 3% as shown in Figure 4.10. In case, wavelet illustration is more opaque, identical methods could be preowned in the wavelet package frame of reference to attain inadequate illustration. Later compute the leading disintegration in accordance to entropy like precedent whichever correlates to the preferred function (de-noising or compression).

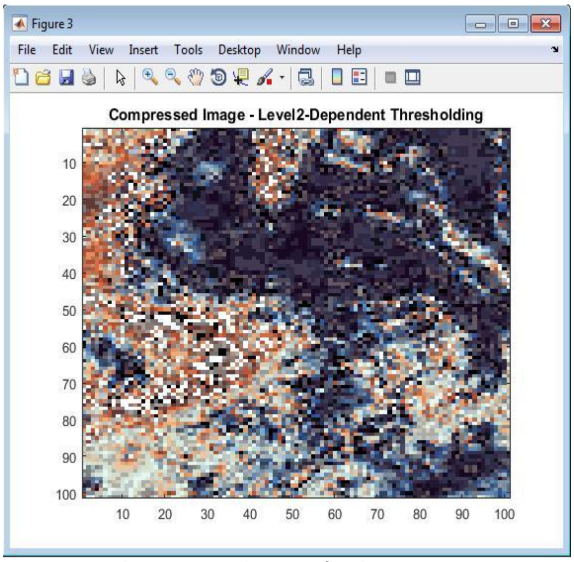


Figure 4.10 Level2 compressed image for data Compression using 2D Wavelet Analysis

Level2 coefficient and density values

Perf12 = 99.7841
Perf22 = 97.9733
Cxd2_density (compression density) = 0.2072

Proposed Bisectional Cylindrical Wavelet Transform (BCWT)

This is the method proposed to compress the satellite image. Here three levels of compresion taken place. The block diagram of proposed method can be represented as,

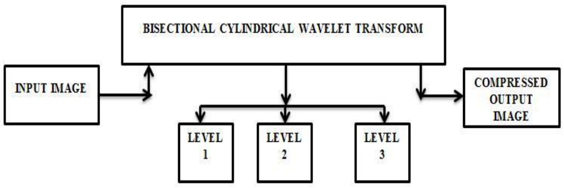


Figure 4.11 Block diagram of Bisectional cylindricalwavelet transform

Level 1 Compression Method

In this method, Topview of compressed satellite image can be represented. The level 1 equation can be represented in Equation (8) as,

$$t = x(0{:}\Pi/1{:}4*\Pi/2) \quad (8)$$

In this method, instead of obtaining complete compressed satellite image only upper level of satellite image is achieved after compression. It interacts with the output image displayed in the current input image as shown in Figure 4.12

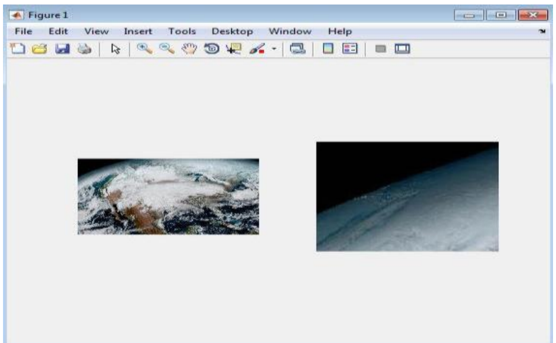


Figure 4.12 Level1 Compressed Image for Bisectional Cylindrical Wavelet transform

Level 2 Compression Method

In this method, compression carried out section wise. It will tilt an image according to its center point and makes the output image large enough to contain the entire compressed image. Uses nearest neighbor interpolation and sets the values of pixels in output image that are outside in compressed image to 0 and it makes the output image the same size as the input image. The level 2 equation can be represented in Equation (9)as

$$t = 0{:}\Pi x \,/\, 10{:}2*\Pi x \quad (9)$$

It observes the image according to the earth observation. Slightly tilted top section of an satellite image is obtained by using level 2 compression method as illustrated in Figure 4.13

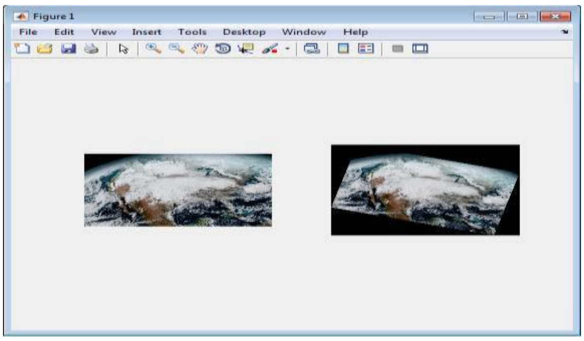


Figure 4.13 Level 2 compressed image for Bisectional cylindrical wavelet transform

Level 3 Compression Method

In this method, it compress the satellite image in the form of cylindrical section base. There won‘t be loss of data during this level of compression. The level 3 equation can be represented in Equation (10)as,

[x,y,z] = cylindrical (2x+sin(t)) (10)

In this case, satellite image can be transmitted quickly. Complete size of an image reduced according to the level 3 compression without any loss of data. This method will be helpful for easy transmission as represented in Figure 4.14.

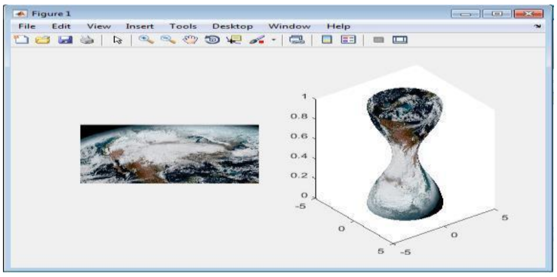


Figure 4.14 Level 3 compressed image for Bisectional cylindrical wavelet transform

Standard parameters are estimated between compressed image and original image of different methods. Maximum value is obtained in the proposed Bisectional cylindrical wavelet transform due to level 3 compression where the output image is compressed to the cylindrical shape without any loss of pixel values.

Table 1: Performance Analysis using Proposed Bisectional Cylindrical wavelet transform with other wavelet transforms

STANDARD PARAMETERS	CWT	SWT	Data compression using 2D wavelet Analysis	Proposed BCWT
PSNR(db)	61.47	51.11	45.58	62.70
SNR(db)	19.26	18.71	17.17	19.45
MAE	0.08	0.09	0.10	0.12
MSE	62.60	51.72	46.12	62.55
CR	85.57	85.14	85.59	85.61
BPP	20.53	20.43	20.54	20.65
THRESHOLD VALUE	0.45	0.45	0.45	0.45

5. Conclusion and Future Work.

In this paper, results of continuous wavelet transform, stationary wavelet transform data compression for 2D wavelet analysis and Proposed Bisectional cylindrical wavelet transform are compared. Standard parameters like PSNR, SNR, MAE, MSE, CR, BPP and threshold value for reconstructed images are tabulated according to the different compression techniques and coefficient, pixel and density values are indicated. In dispersion of four methods, proposed Bisectional Cylindrical wavelet transform provides efficient progress in levels of compression. According to the proposed bisectional cylindrical wavelet transform, PSNR, MSE, BPP and CR values are concentrated to obtain better compressed satellite image. Correlated to other wavelet transform, proposed wavelet transform afford better PSNR, reduced MSE, improved compression ratio and BPP value. In future, the above work will be carried out by implementation of satellite image decompression using VHDL code with efficient decompression algorithm.

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