Accurate 3D information extraction from large-scale data compressed image and the study of the optimum stereo imaging method

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ABSTRACT

The paper reports the accurate height information extraction method under the condition of large-scale compressed images, and proposes the optimum stereo imaging system using the multi-directional imaging and the time delay integration method.

Recently, the transmission data rate of stereo images have increased enormously accompany by the progress of high- resolution imaging.

Then, the large-scale data compression becomes indispensable, especially in the case of the data transmission from satellite. In the early stages the lossless compression was used, however the data-rate of the lossless compression image is not sufficiently small. Then, this paper mainly discusses the effects of lossy compression methods.

First, the paper describes the effects for JPEG compression method using DCT, and next analyzes the effects for JPEG2000 compression method using wavelet transform. The paper also indicates the effects of JPEG-LS compression method. The correlative detection techniques are used in these analyses.

As the results, JPEG2000 is superior to former JPEG as foreseeing, however the bit error affects in many vicinity pixels in the large-scale compression. Then, the correction of the bit error becomes indispensable. The paper reports the results of associating Turbo coding techniques with the compressed data, and consequently, the bit error can be vanished sufficiently even in the case of noisy transmission path.

Finally, the paper proposes an optimum method for the stereo imaging from satellite, using multi-directional imaging and motion image compression techniques, and also adopting the time delay integration techniques. As a result, high accuracy and high-resolution stereo imaging can be achieved under the condition of large-scale image compression.

1 INTRODUCTION

In recent years, the resolution of the image data sending from space has remarkably progressed to fine grade. Accompany by this resolution progress, the data rate of the image have increased enormously.

Previously, many kinds of data compression techniques were developed to reduce the data rate.

In early stages, the predictive coding methods have been used, because of the simplicity and loss less characteristics. However, the compressed data rate is not sufficiently small in the lossless compressed methods. Then, the adopting the lossy compression techniques will be indispensable.

In the lossy compression techniques there are somewhat degradation of image quality. Ordinarily, the value of signal to noise ratio(S/N) has been used for the estimation of the quality of the compressed image. However, the value of S/N decreases gradually by the compression ratio. For the analysis of remote sensing data, more definite estimation will be required. In this paper, error analysis is used for the height detection from the stereo images.

2 IMAGE DATA TRANSMISSION FROM SATELLITE

2.1 Transmission System and Data Rate of High Resolution Images

Figure 1 shows the example block diagram of data transmission system from satellite. The image data of the ground surface are taken by linear array CCD sensor, and converted to electrical signal. The information data rate is given by following equation.

$$DataRate = \frac{m \times N_b \times N_q}{\tau_0} \quad (1)$$

Where, m=number of pixels per line, N_b=number of observation bands, N_q =number of bits per pixel.

• is a integration time or imaging period per line, when W_E is a ground pixel size, and v is a relative velocity of the satellite, • is ordinarily set to following relations.

$$\hat{O} = \frac{W_E}{V} \quad (2)$$

The typical value of the data rate is in the case of m=10,000, N_b=4, N_q =8, v=7km/sec., and W_E=1m, data rate reaches approximately 2.24Gbps without any additive synchronous code or error correcting code.

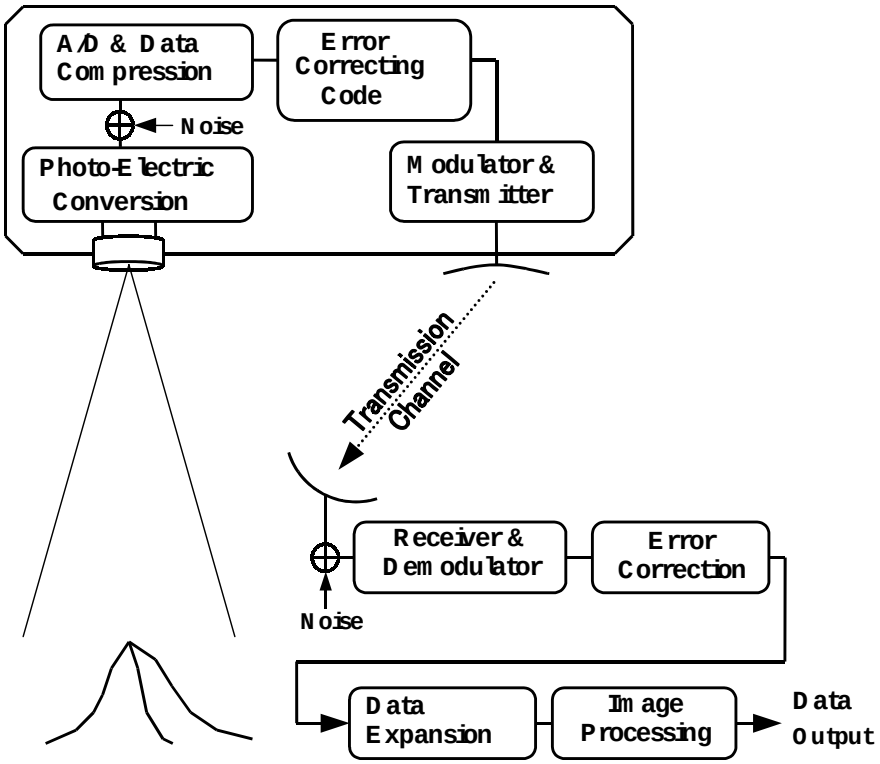


Figure 1. Block diagram of Image Transmission from Satellite

The width of the transmission channel from the satellite to the ground station is not sufficient to transmit these wideband data. Then it is necessary to adopt data compression techniques in the high-resolution system.

2.2 High Quality Data Compression

2.2.1Lossless Compression

In the sense of accurate transmission of the data, it is required to use the lossless compression method. In the early stage the predictive coding was used to compress the image data, however compression ratio becomes insufficient in the above wide band image data.

2.2.2 JPEG-DCT, JPEG2000 and JPEG-LS Compression[1] [2]

In the high-resolution image transmission system, the large scaled data compression techniques are required. Then, the adopting the lossy compression system becomes necessary. JPEG-DCT is now widely used for its simplicity of hardware and easiness to compress the image data into small value. However, when the compressed data becomes small, the error of the JPEG-DCT causes sometimes un-allowable degradation of the image quality.

In this paper the compression ratio is defined to following relation.

Compression Ratio = compressed data size / original data size (3)

This means when the input image data are consists of 8 bits, compression ratio=0.125 corresponds to 1 bit per pixel. Figure 2 shows the sample of the compressed and expanded image using JPEG-DCT. Left image is the original image and the center image shows the recovered image using JPEG-DCT.

It is not easy to recognize the degradation of the image, but the compressed (center) image has lack of high frequency component, and the block noise can be seen at the smooth part of face and shoulder.

(a) Original Image (b) Image of JPEG-DCT (c) Image of JPEG2000

Figure 2. Example image of JPEG-DCT and JPEG2000 (compression ratio = 0.1)

To improve the quality of the compressed image, JPEG2000 compression method was developed. The JPEG2000 method adopts the wavelet transform instead of discrete cosine transform in the JPEG-DCT. Figure 3 shows the block diagram of JPEG2000 standard system. An example recovered image using JPEG2000 is shown in Figure 2(c). This image has also lack of some high frequency component, but the block noise is not recognized.

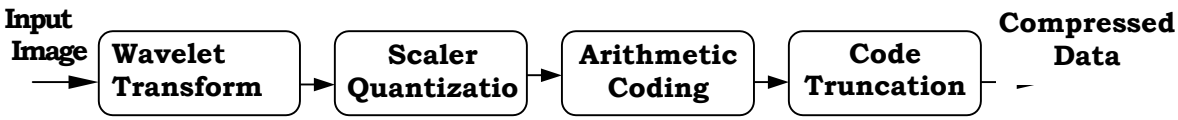


Figure 3. Block diagram of JPEG2000 Compression System

Another attractive compression method is JPEG-LS, which is an essentially lossless coding until to some limit of compression ratio. However, in the compression ratio becomes less than 0.15, the error increases rapidly, as can be seen in the figure 4.

(a) Compression Ratio =0.156 (a) Compression Ratio =0.10

Figure 4. Example image of JPEG-LS Coding

3 HEIGHT INFORMATION EXTRACTION FROM STEREO IMAGES

3.1 Stereo Imaging from Space

The high-resolution stereo imaging from space will perform important roll in the monitoring or prevention of disasters and other many fields. The stereo imaging from space requires essentially two times data quantity than usual 2 dimensional images. Then, the data compression is indispensable especially in stereo imaging system. The height information can be extracted using correlation analysis by computer, then the degradation of the image sometimes occur fatal error. Accordingly, the analysis of the quality of data compressed image becomes excessively important matter.

3.2 Correlation Analysis

The height information extraction is usually executed by correlation analysis. Figure 5 shows the principle diagram of correlation analysis.

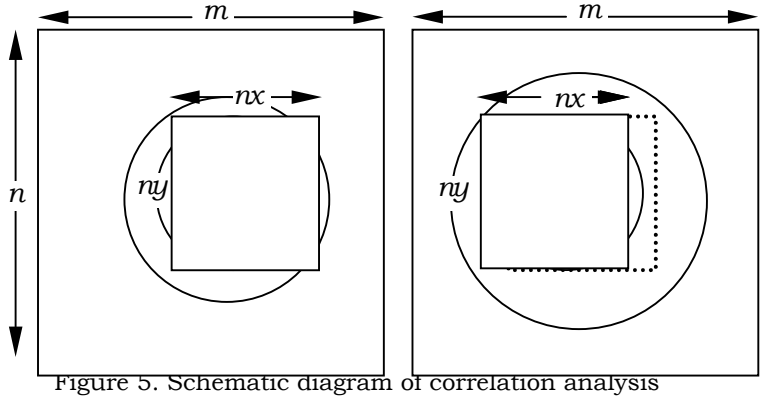


Figure 5. Schematic diagram of correlation analysis

The mutual correlation value of the two images is acquired by the following equation.

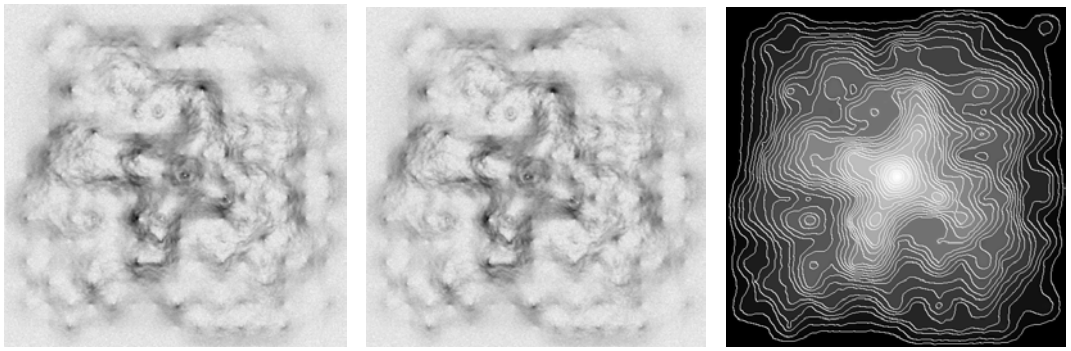
$$\rho(i,j,kx,ky)=\frac{\sum_{v=j}^{v=j+ny}\sum_{u=i}^{u=i+nx}\left\{V1(u,v)-\overline{V1}\right\}\left\{V2(u-kx,v-ky)-\overline{V2}\right\}}{\sqrt{V1\sigma\cdot V2\sigma}} \quad (4)$$

Where, $\overline{V_1},\overline{V_2},V_{1\sigma},V_{2\sigma}$ are mean values and deviations of V_1 and V_2 .

4 SIMULATION RESULTS OF HEIGHT INFORMATION EXTRACTION

4.1 Simulation Results without Data Compression

Figure 6 shows the example data height extraction from stereo pair images without data compression or without any additive noise. Figure 6(c) shows the correlation analysis achieved good results.



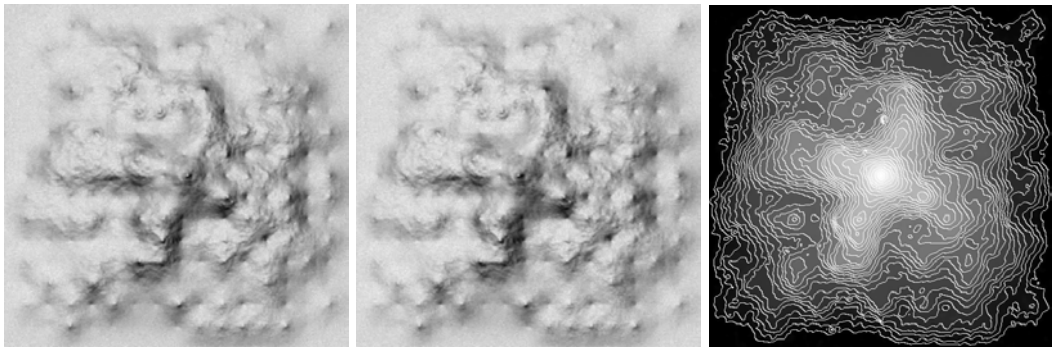
(a) Forward Image (b) Backward Image (c) Height Data Output

Figure 6. Height Information Extraction from Stereo pair Images

4.2 Simulation Results with Data Compression

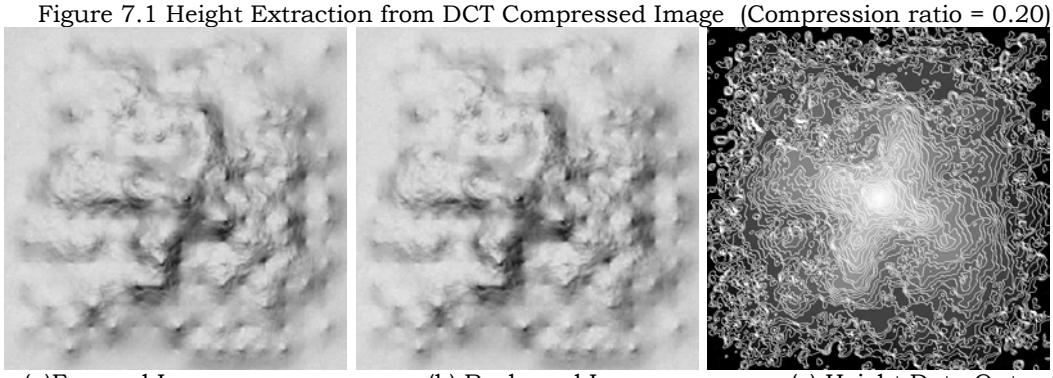
4.2.1 Simulation results using JPEG-DCT

Figure 7.1 and 7.2 show the simulation results of correlation analysis for the compressed image using JPEG-DCT. In the case of compression ratio is 0.10, many errors occur in the height data output.



(a) Forward Image (b) Backward Image (c) Height Data Output (error pixels = 3.2 %)

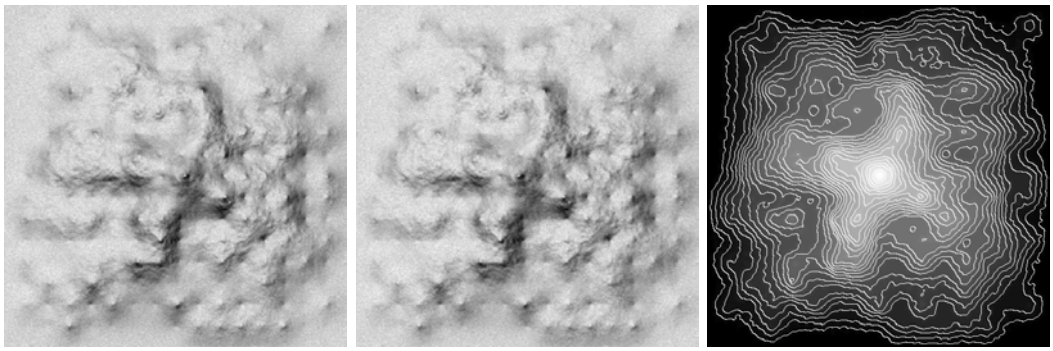
Figure 7.1 Height Extraction from DCT Compressed Image (Compression ratio = 0.20)



(a)Forward Image (b) Backward Image (c) Height Data Output (error pixels = 28 %)

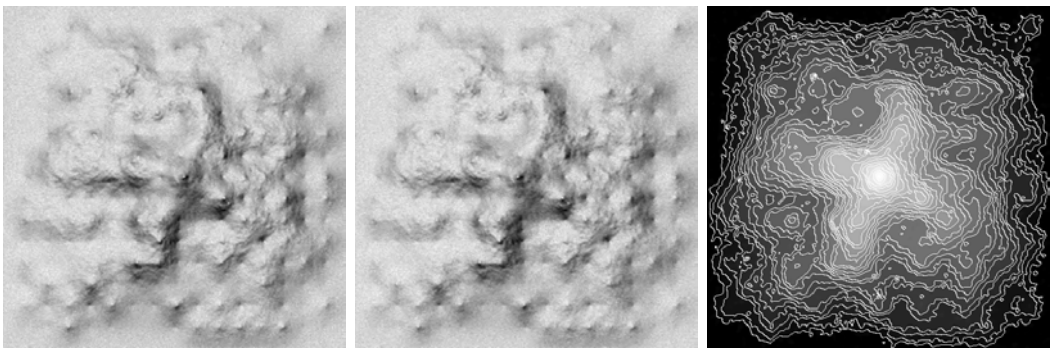
Figure 7.2 Height Extraction from DCT Compressed Image (Compression ratio = 0.10)

4.2.2 Simulation results using JPEG2000



(a) Forward Image (b) Backward Image (c) Height Data Output (error pixels = 0.5 %)

Figure 8.1 Height Extraction from JPEG2000 Compressed Image (Compression ratio = 0.19)



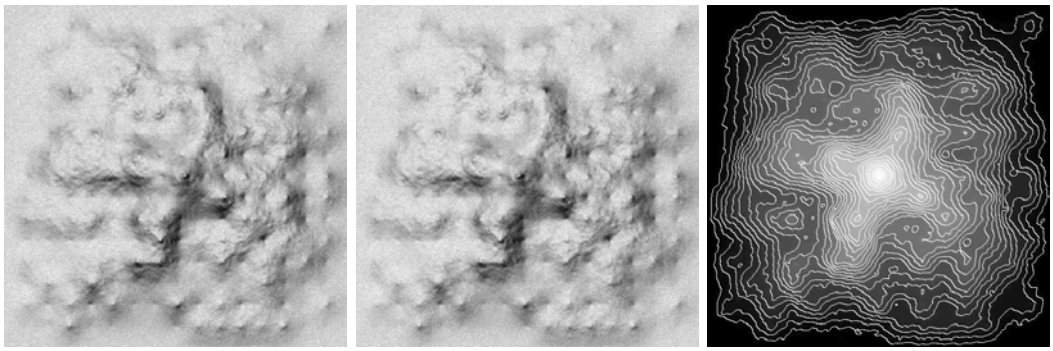
(a) Forward Image (b) Backward Image (c) Height Data Output (error pixels = 3.4 %)

Figure 8.2 Height Extraction from JPEG2000 Compressed Image (Compression ratio = 0.10)

Figure 8.1 and 8.2 show the simulation results of correlation analysis for the compressed image using JPEG2000. In the JPEG2000 coding, errors do not increase rapidly such as in the case of JPEG-DCT.

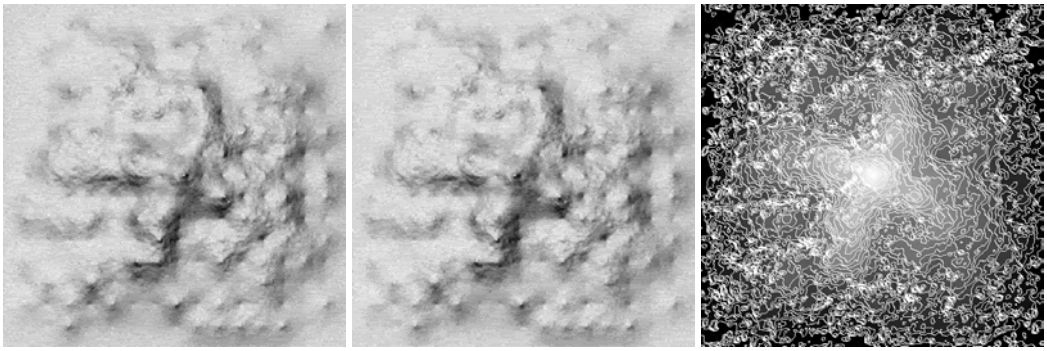
4.2.3 Simulation results using JPEG-LS

Figure 9.1 and 9.2 show the simulation results of correlation analysis for the compressed image using JPEG-LS. In the JPEG-LS coding, errors are small at the compression ratio is 0.19, but rapidly increase in the compression ratio is 0.1.



(a) Forward Image (b) Backward Image (c) Height Data Output (error pixels = 0.75 %)

Figure 9.1 Height Extraction from JPEG-LS Compressed Image (Compression ratio = 0.19)



(a) Forward Image (b) Backward Image (c) Height Data Output (error pixels = 27 %)

Figure 9.2 Height Extraction from JPEG-LS Compressed Image (Compression ratio = 0.10)

4.2.4 Comparison of errors for each compression method.

Figure 10 shows the number of error pixels to each compression method. Jpeg2000 coding is superior as forseeing.

JPEG-LS compression is also good results in the range of not less than 1/5. The error pixels of JPEG-DCT are comparatively bigger than other methods. Probably block noise causes the error in the process of correlation analysis.

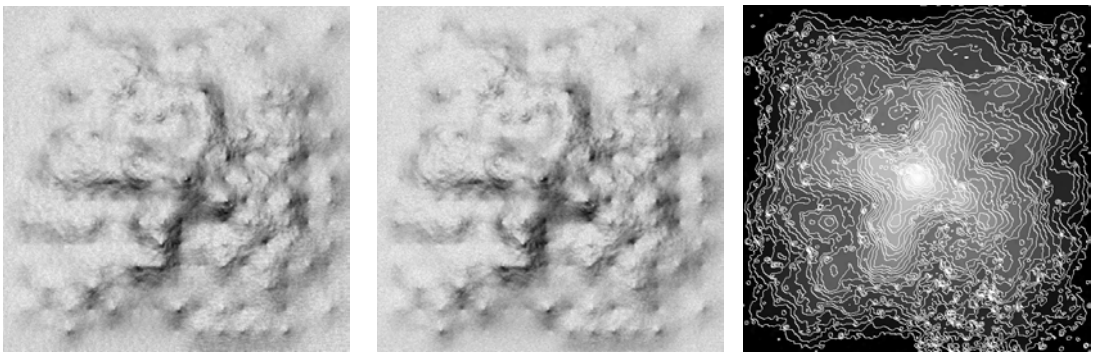
Number of Error Pixels (%)

Compression Ratio
Figure 10. Number of Error pixels in the height detection

5 THE EFFECTS OF BIT ERROR AND ERROR CORRECTION

5.1 The Bit Error Effects for Height Data Analysis

In the large scaled compression system, the bit error sometimes affects to many vicinity pixels. Figure 11 shows the increasing error pixels due to bit error. In this case, the error rate is approximately 2*10E-5, that causes the increasing error pixels more than ten times compare than the case of bit error does not existing.

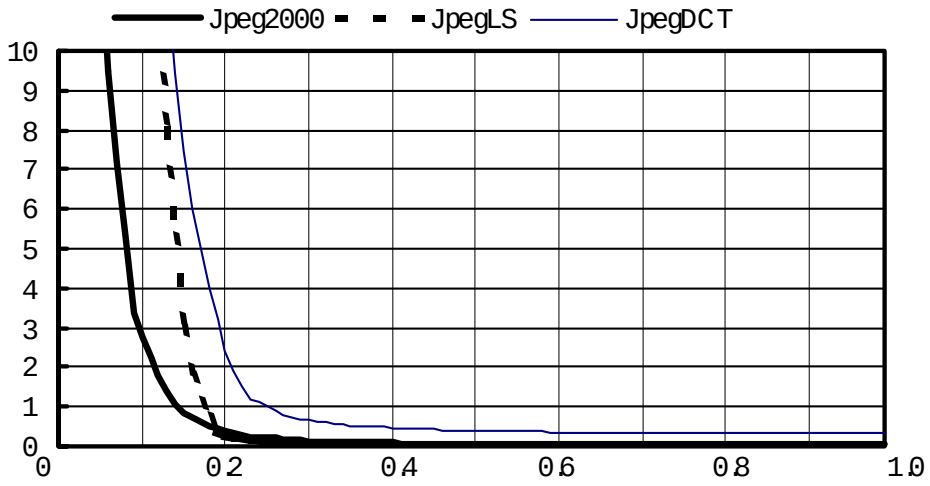


(a) Forward Image with error (b) Backward Image with error (c) Height Data Output (error pixels = 9.4 %)

Figure 11. Effects of bit error for JPEG2000 compressed data. Compression Ratio = 0.19, Bit Error Rate = 2*10E-5

5.2 Error Correction [3]

Recently, the progress of error correcting code is remarkable, especially, Turbo coding or LDPC code achieved superior results for error correction. We also tested the bit error characteristics of Turbo code compare to ordinary BPSK modulation, as shown in the figure 12. It is obvious to vanish out the bit error in the range of E_b/N_0 is greater than 3 or 4 dB in the case of iteration is greater than 5 times.



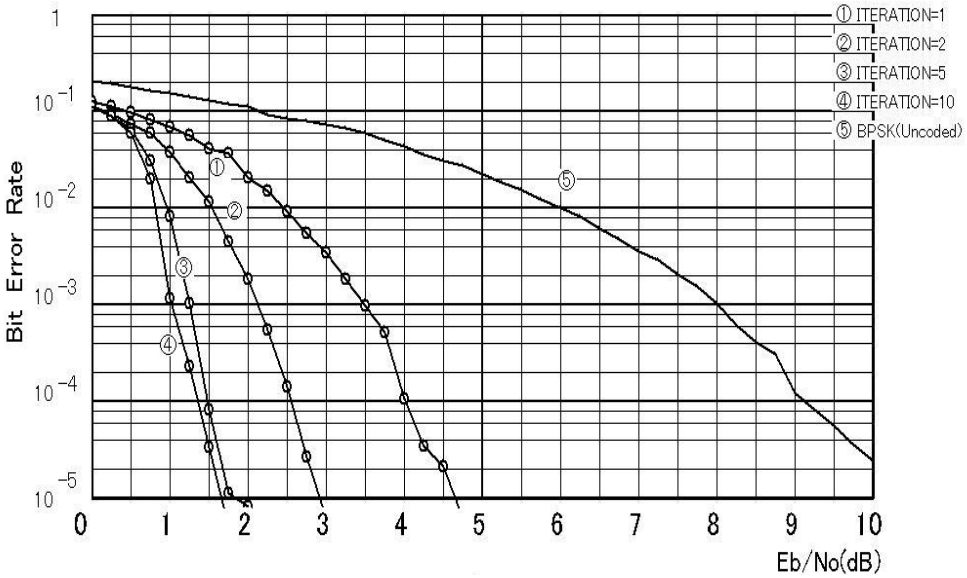


Figure 12. Error Rate Characteristics of Turbo code and un-coded BPSK

6 THE FURTHER IMPROVEMENTS BY MULTIDIRECTIONAL AND TDI IMAGING

As shown in the first figure 1, another noise exists in the head of sensor system. Accompany the progress of high-resolution imaging, the incident energy into the sensor significantly decreases, the improvement of S/N becomes important matter.

For this S/N improvement, TDI(time delay integration) techniques are effective[4]. For the accurate height extraction, the multi-directional stereo imaging is also important to avoid unseen region. In this system, the increase of the data rate can be reduced by using the techniques of motion image compression[5]. Then multidirectional and TDI imaging are both important for high resolution stereo imaging. Figure 13 shows the principle schematic diagram suitable for future high-resolution stereo system.

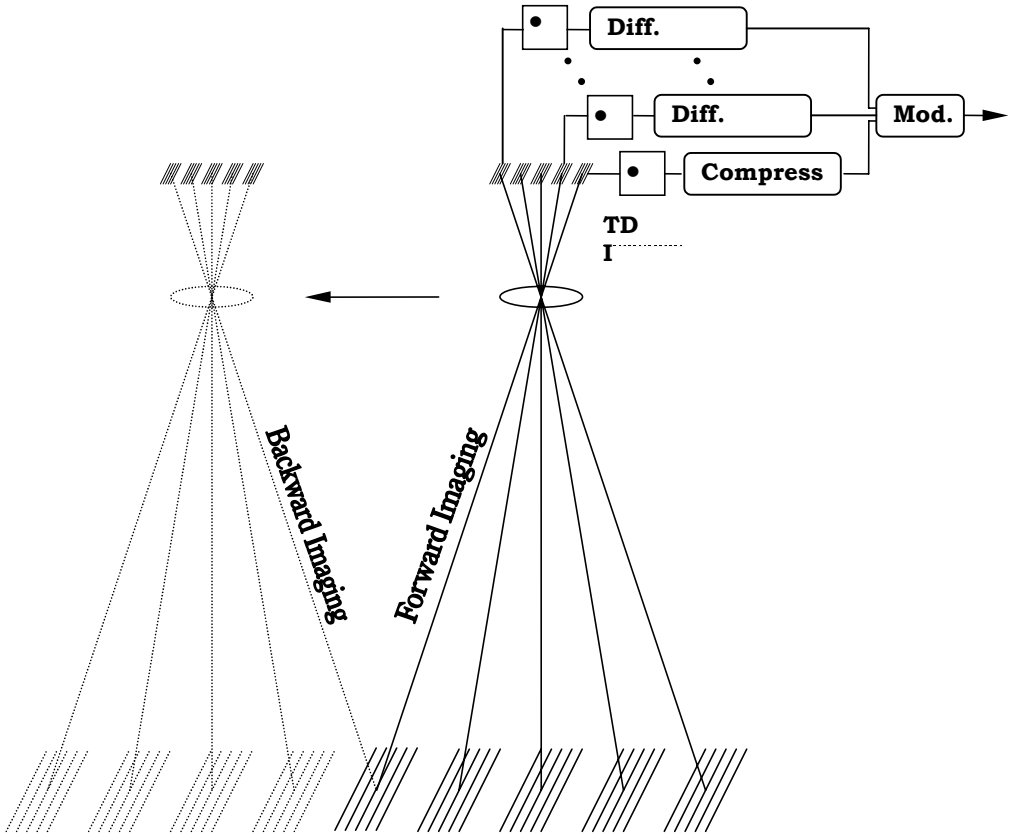


Fig 13. Multidirectional

Stereo and TDI Imaging System

7 CONCLUSIONS

The paper has cleared up the desired value of data compression ratio for stereo imaging, by using the correlation analysis and using the estimation of the error pixels number.

JPEG2000 compression is clearly superior to JPEG-DCT. JPEG-LS compression shows also good results in the range of compression ratio is not less than 1/5. In every method, error correction is important and remarkably effective.

Furthermore, multidirectional and TDI imaging will become important matter especially for high-resolution stereo imaging.

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