

3D Wavelet Compression

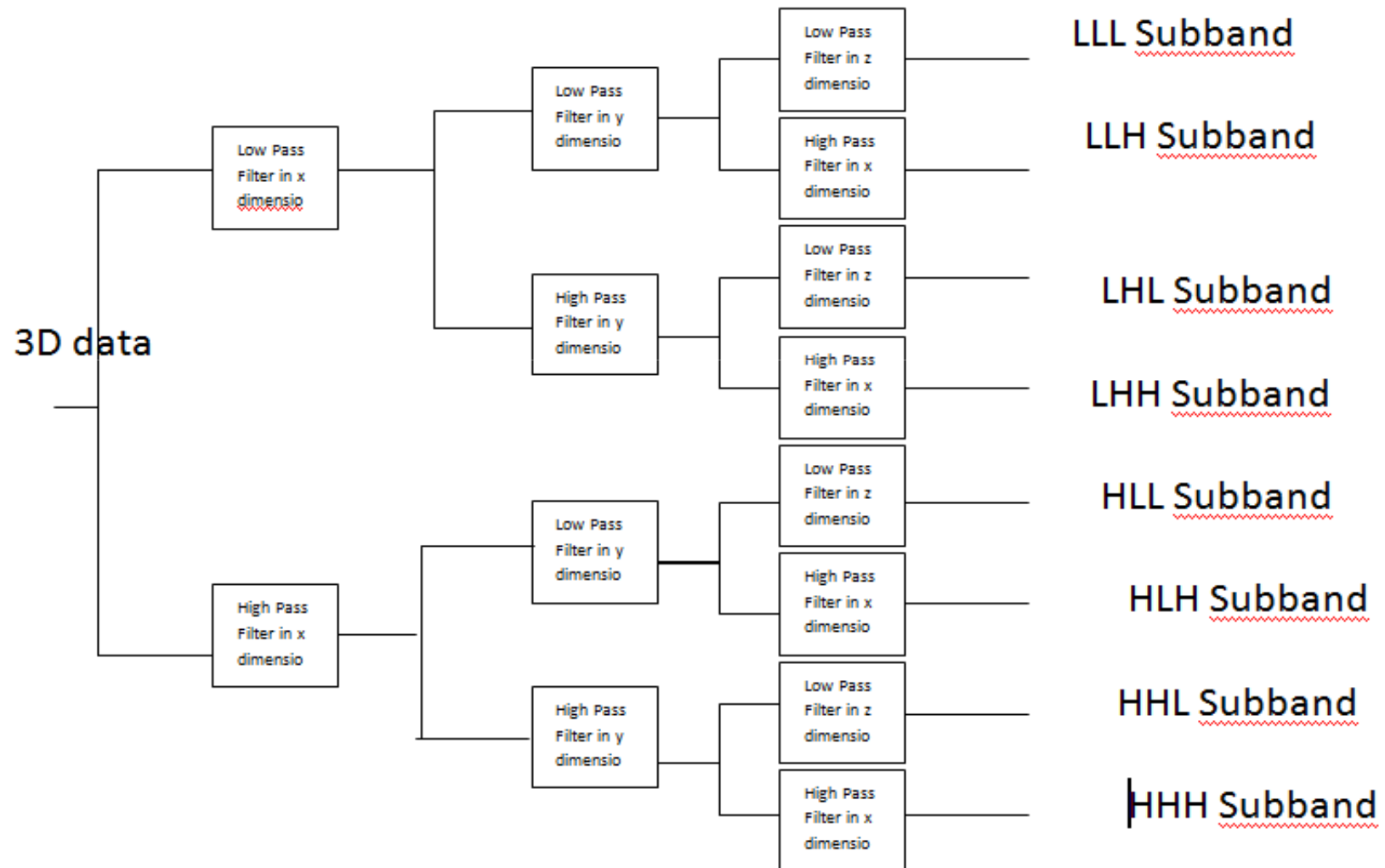
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Project Guides:

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3D level 1 Wavelet decomposition



Thresholding Scheme

- **Parameter of Thresholding**

- Percentage of wavelet coefficients contributing maximum energy for a frequency branch

- **Energy Ratio**

- $E = \text{Energy of coefficients after thresholding} / \text{energy of coefficients of original data}$
For good reconstruction this ratio must be high

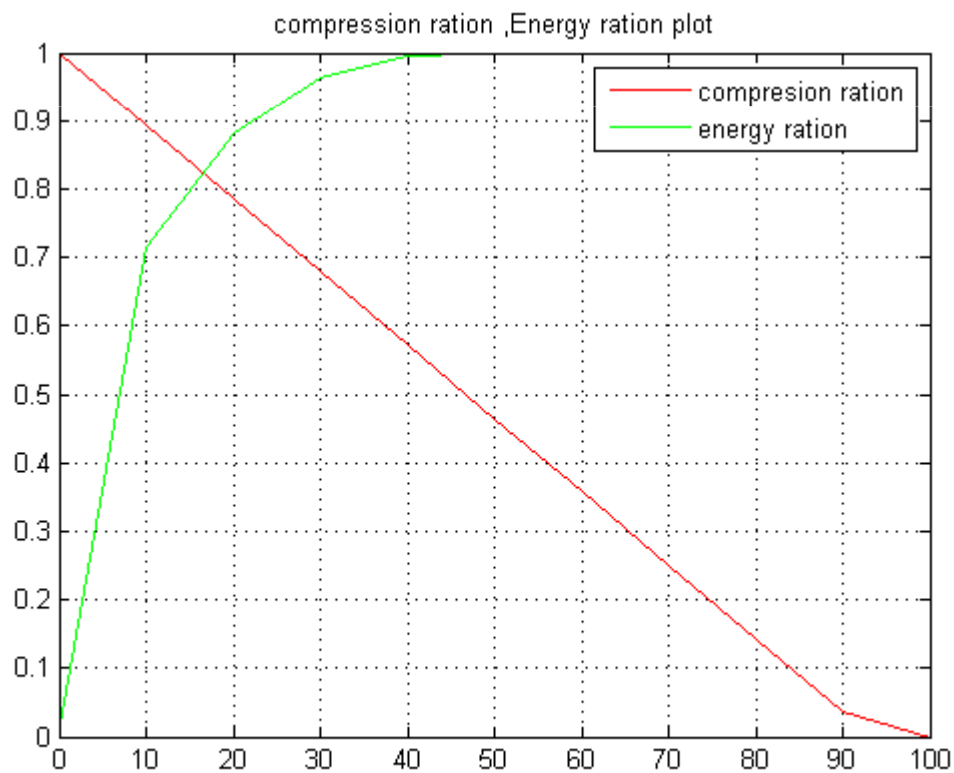
- **Compression Factor**

- $C = \text{change in length of data after thresholding} / \text{length before thresholding}$

This factor tells amount of data reduced due to thresholding .For good compression this ratio is required to be high

Optimal threshold

- Tradeoff between energy ratio and compression ratio
- Plot of Energy ratio V/s Compression ratio



Optimal Threshold

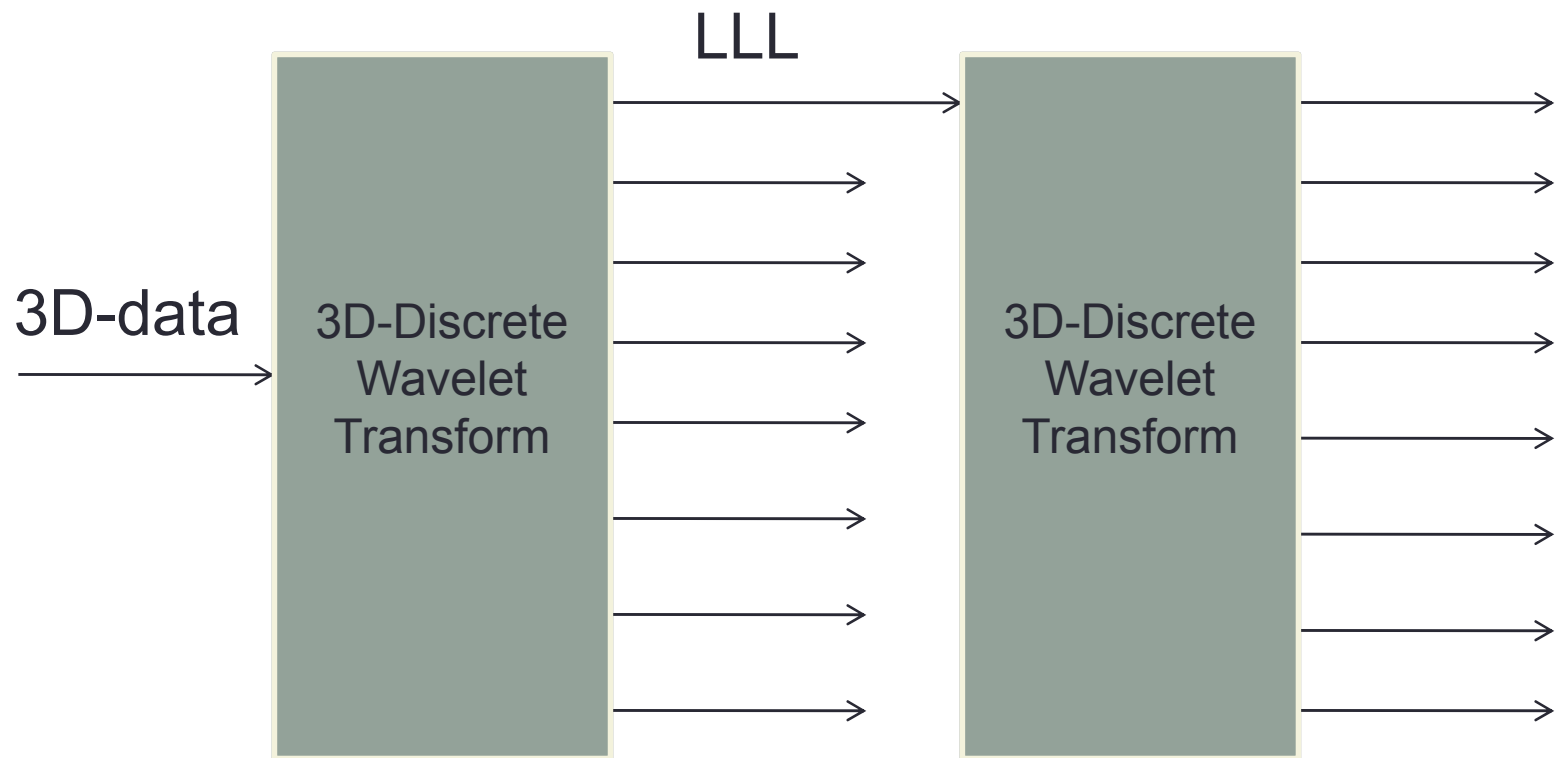
- Optimal Threshold is percentage of dominant coefficients required to be retained to give the best energy retention and highest compression ratio
- Quality of reconstructed data can be represented using PSNR measurement.
- $$\text{PSNR} = 20 \cdot \log \left(\frac{\text{Peak Value}}{\sqrt{\text{mean square error}}} \right)$$

Performance of Thresholding Operation

- Level 1 decomposition

'wavelet '	'PSNR' (db)	Reduction factor	level
Bior 4.4	106.9422	4.2375	1
Bior 2.2	102.8333	3.8690	1
Symlet 4	104.1897	4.2830	1
Daub 4	103.8591	4.2826	1
Daub 8	106.0661	4.4519	1

Level 2 Wavelet decomposition



Level 2 decomposition

'wavelet '	'PSNR'	reduction	level
Bior 4.4'	89.0869	7.0716	2
Bior 2.2	86.6147	6.3079	2
Symlet 4	85.8092	7.1591	2
Daub 4	85.5333	7.1584	2
Daub 8	86.6147	7.5210	2

- Average reduction of 18 db in PSNR

Level 3 decomposition

'wavelet '	'PSNR'	reduction	level
Bior 4.4	77.8364	7.9499	3
Bior 2.2	75.6838	7.0016	3
Symlet 4	74.7534	7.9965	3
Daub 4	72.7517	7.9957	3
Daub 8	74.7534	7.9957	3

- Bior 9/7 at level 3 decomposition provides the best performance in terms of PSNR .

Level 5 decomposition

'wavelet '	'PSNR'	compression	level
Bior 4.4	68.6797	8.1735	5
Bior 2.2	62.7099	7.1600	5
Symlet 4	64.3775	8.1906	5
Daub 4	59.9146	8.1886	5
Daub 8	59.9146	8.7812	5

Analysis

- Increasing number of decomposition levels and thresholding decreases PSNR at the cost of increase in data redundancy .
- Low pass branch is divided again and HP branches are thresholded .This leads to loss of low pass detail hence decrease in PSNR
- Thresholding components increases number of zeros hence we can achieve better compression results
- As number of decomposition level increases PSNR decreases by a large amount with no significant gain in data redundancy .Maximum decomposition level of 3 is choose in further analysis

Zero Run Length Encoding

- At each level zero run length encoding is performed.
- Input is the threshold wavelet coefficients and minimum run length
- Hence only runs of zeros are encoded
- If the number of continuous zeros are greater than minimum run length, run length encoding is performed.
- Run length=2
- 0 0 0 1 2 3 0 0 1 2 0 0 0
- 0 3 1 2 3 0 0 1 2 0 3

Encoding

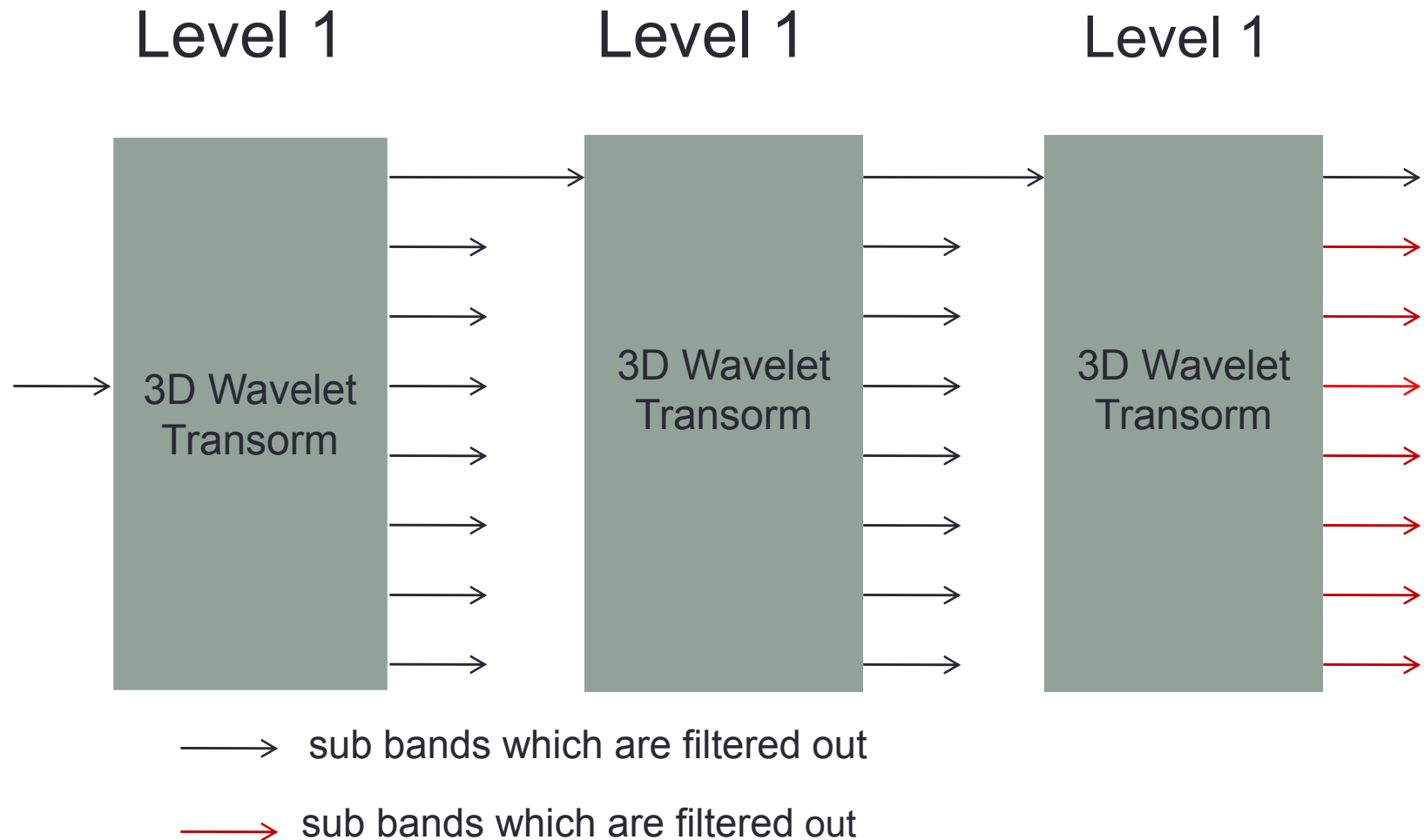
- Input image is a gray level image In range (0-255)
1 byte can be used to represent intensity value of input data.
- Output Data is represented using single precision data type .Each data point requires 4 bytes for storage.
- The encoding performance is measured using compression ratio in bytes
- $CR = \frac{\text{Number of byte of input}}{\text{number of byte of of encoded data}}$

Level 2/3 decomposition After encoding

'wavelet '	'PSNR'	compression	level
'bior 4.4'	89.0869	0.9010	2
'bior 2.2	86.6147	0.9506	2
sym4	85.8092	0.9521	2
db4	85.5333	0.9534	2
db8	86.6147	0.8192	2

'wavelet '	'PSNR'	compression	level
'bior 4.4'	77.8364	0.9423	3
'bior 2.2	75.6838	0.9936	3
sym4	74.7534	0.9962	3
db4	72.7517	0.9971	3
db8	74.7534	0.8521	3

Level 3 decomposition with less dominant high pass branches filtered out



Level 3 decomposition with less dominant high pass branches filtered out

After Level 1 decomposition

- 1 Low pass bands

- 7 High pass bands

After Level 2 decomposition

- 1 Low pass band of 2nd level

- 7 High pass bands of 2nd level

- 7 High pass bands of 1st level

After Level 3 decomposition

- 1 Low pass band of 3rd level

- 7 High pass bands of 3rd level

- 7 High pass bands of 2nd level

- 7 High pass bands of 1st level

Level 3 decomposition with least dominant high pass branches made to 0

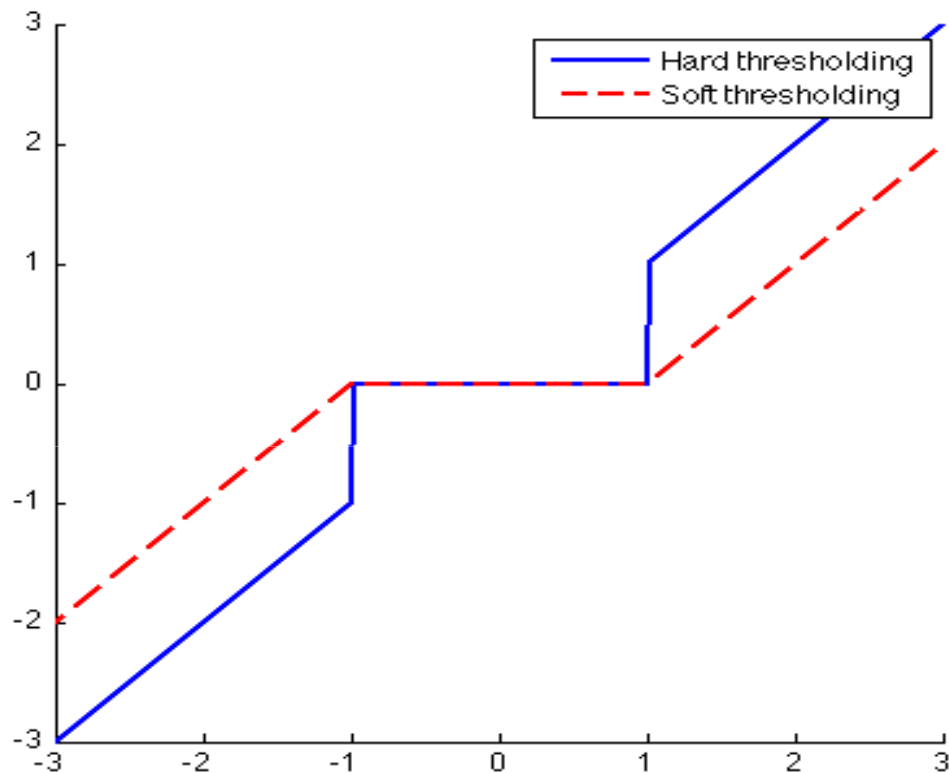
'wavelet '	'PSNR' db	Compression
'bior 4.4'	73.7776	5.4023
'bior 2.2	71.1070	6.3509
sym4	71.1070	6.1787
db4	69.9302	6.1285
db8	69.9302	4.2036

High pass band
truncated

'wavelet '	'PSNR'	compression
'bior 4.4'	77.8364	0.9423
'bior 2.2	75.6838	0.9936
sym4	74.7534	0.9962
db4	72.7517	0.9971
db8	74.7534	0.8521

Only thresholding

Hard and Soft Thresholding:



De-noising is carried out using soft thresholding techniques

Compression is carried out using hard thresholding techniques

Hard and soft thresholding for 3% noisy data

'wavelet '	'PSNR'	compression	level
'bior 4.4'	68.8817	5.2111	3
'bior 2.2	66.6903	6.0528	3
sym4	67.3014	6.0521	3
db4	66.6441	5.9953	3
db8	66.3837	4.1122	3

Using Hard
Thresholding

'wavelet '	'PSNR'	compression	level
'bior 4.4'	68.881	5.2162	3
'bior 2.2	66.700	6.0540	3
sym4	67.3143	6.0498	3
db4	66.3807	5.9957	3
db8	67.8374	4.1136	3

Using Soft
Thresholding

Soft and hard thresholding for 5% noisy data

'wavelet '	'PSNR'	compression	level
'bior 4.4'	63.7425	4.8016	3
'bior 2.2	62.2676	5.4010	3
sym4	62.8029	5.7748	3
db4	62.2063	5.7749	3
db8	63.1374	3.8843	3

Using Hard
Thresholding

'wavelet '	'PSNR'	compression	level
'bior 4.4'	63.7443	4.9337	3
'bior 2.2	62.2804	5.4095	3
sym4	62.8097	5.8245	3
db4	62.2041	5.7764	3
db8	63.1333	3.9188	3

Using Soft
Thresholding

Soft and hard thresholding for 9% noisy data

'wavelet '	'PSNR'	compression	level
'bior 4.4'	58.1388	4.1766	3
'bior 2.2	57.2041	4.7419	3
sym4	57.8074	5.0524	3
db4	57.807	5.0685	3
db8	57.8074	3.3876	3

Using Hard
Thresholding

'wavelet '	'PSNR'	compression	level
'bior 4.4'	58.1364	4.2235	3
'bior 2.2	57.2110	4.7529	3
sym4	57.6571	5.0926	3
db4	57.3109	5.0695	3
db8	57.8419	3.3919	3

Using Soft
Thresholding

Analysis

- Bior 9/7 provides the best performances in terms of PSNR and good compression.
- Sym4 wavelet provides the best performance in terms of compressions

Normalization of input data

- The dynamic range of frequency components was very high.(variance in frequency domain)
- In order to reduce the dynamic range the input data was normalized from 0-1.This reduces dynamic range of the frequency components.
- This reduces the dynamic range of frequency values. This enables us to perform further encoding schemes on the data

'wavelet '	'PSNR'	compression	max	variance
'bior 4.4'	63.7443	4.9337	4594.6	859.7036
'bior 2.2	62.2804	5.4095	6373.0	1087.1
sym4	62.8097	5.8245	4870.6	921.0991
db4	62.2041	5.7764	5485.2	940.9748
db8	63.1333	3.9188	6000.4	892.8157

Without
Normalization

'wavelet '	'PSNR'	compression	max	variance
'bior 4.4'	63.7443	4.9337	18.0181	3.3714
'bior 2.2	62.2804	5.4095	24.9921	4.2632
sym4	62.8097	5.8245	19.1005	3.6118
db4	62.2041	5.7764	21.5107	3.6901
db8	63.1333	3.9188	23.5311	3.5012

Normalized
Data

Quantization

- We observe the effect of quantization (with 0.125 & 0.25 step-size) on compression.
- By quantizing the wavelet coefficients, we can get more compression by compromising distortion to a reasonable extent.

'wavelet '	'PSNR'	compression
'bior 4.4'	63.7443	4.9337
'bior 2.2'	62.2804	5.4095
sym4	62.8097	5.8245
db4	62.2041	5.7764
db8	63.1333	3.9188

Unquantized data

Quantization Step-
size = 0.125

'wavelet '	'PSNR'	compression
'bior 4.4'	63.4585	5.6294
'bior 2.2	62.1862	5.7269
sym4	62.5713	6.3650
db4	61.9982	6.3050
db8	62.8866	4.4273

Quantization Step-
size = 0.25

'wavelet '	'PSNR'	compression
'bior 4.4'	63.0286	8.3118
'bior 2.2	61.8610	8.2380
sym4	62.1529	9.0265
db4	61.5596	8.9269
db8	62.4258	6.1876

Quantization

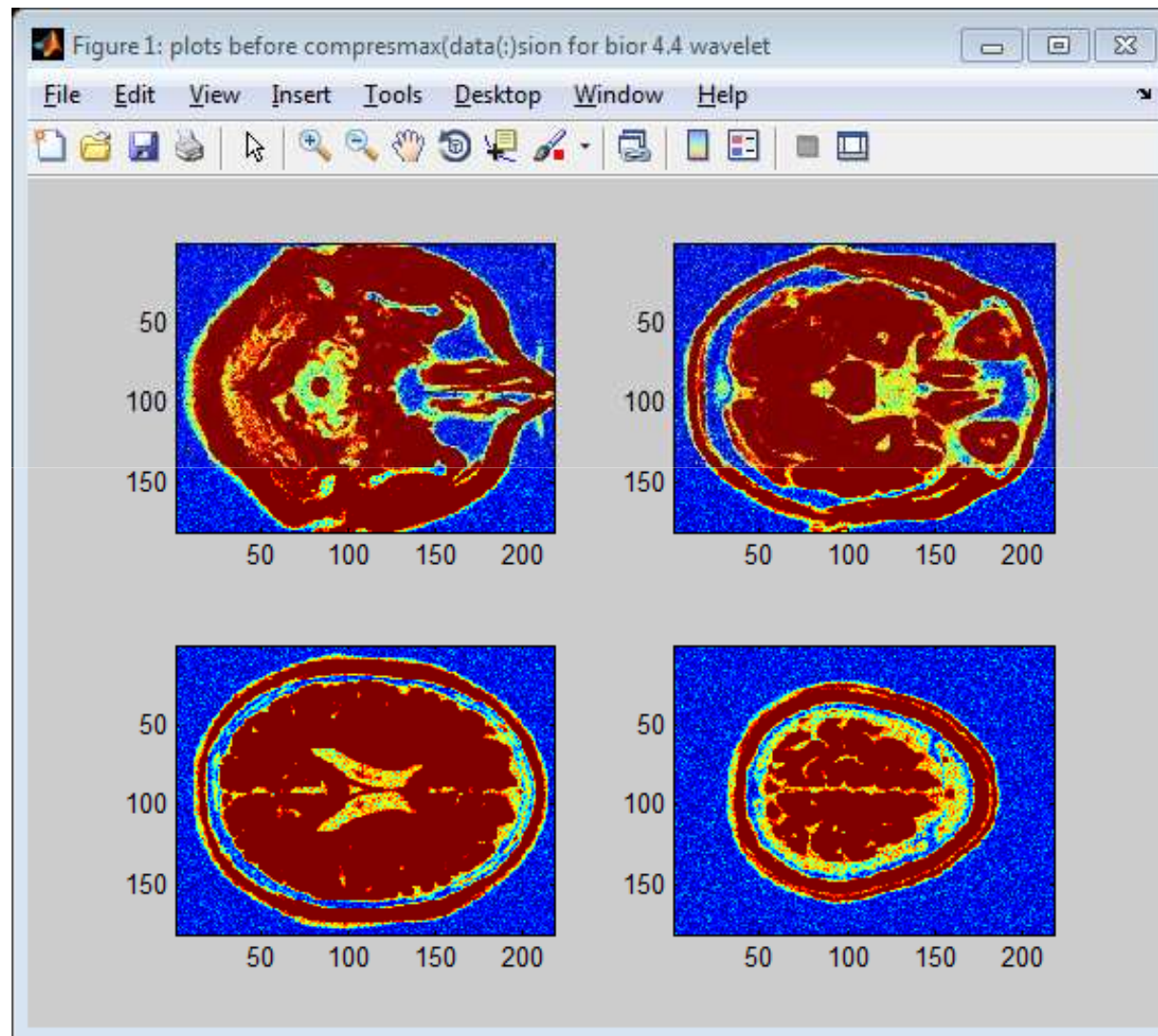
- Quantization step of 0.75

'wavelet '	'PSNR'	compression
'bior 4.4'	59.7821	20.3430
'bior 2.2'	60.1845	17.3377
sym4	59.2625	20.5726
db4	58.9479	20.1492
db8	59.5031	12.7980

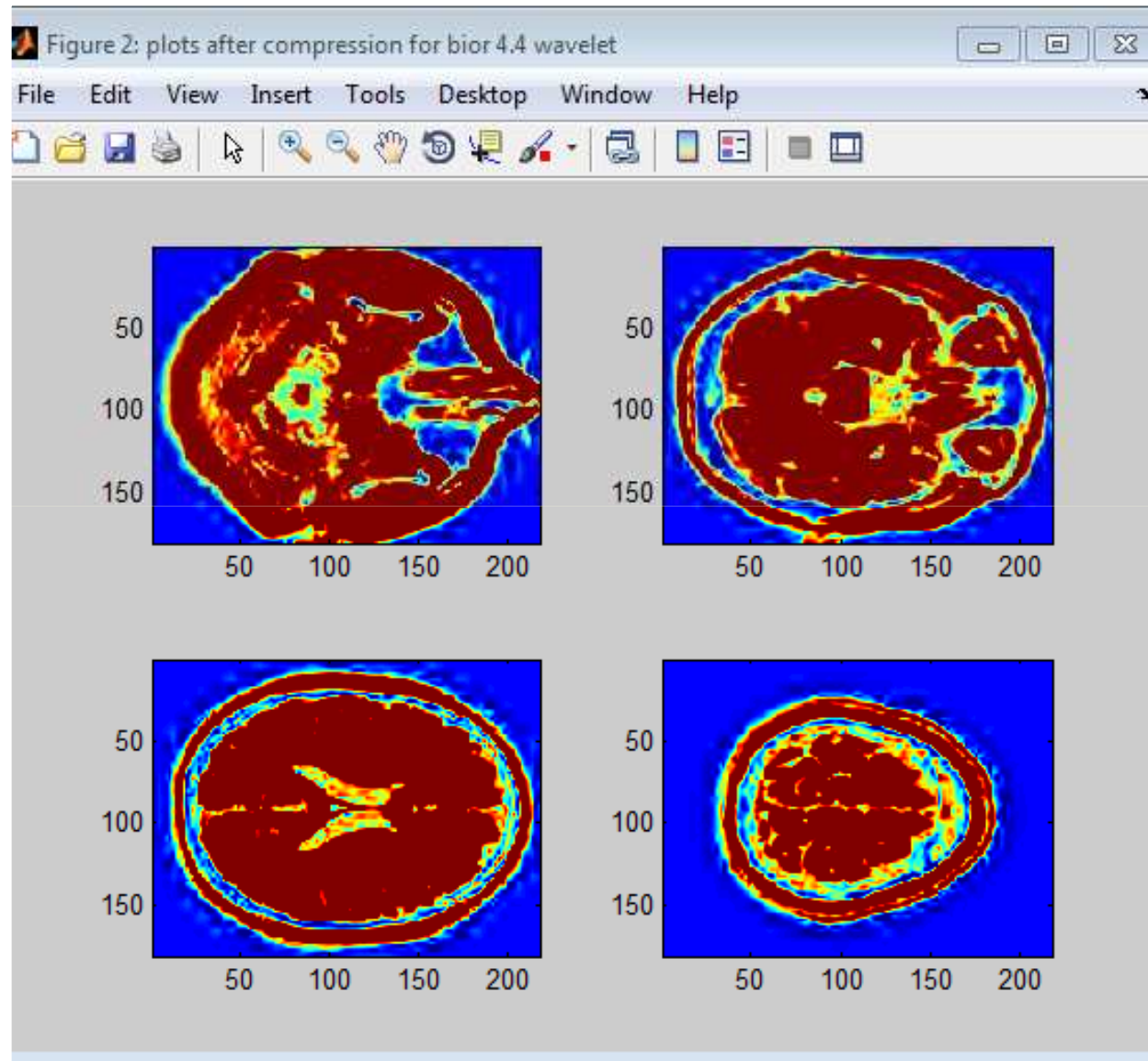
- Quantization step of 1

'wavelet '	'PSNR'	compression
'bior 4.4'	57.4495	25.5181
'bior 2.2'	58.3355	22.4933
sym4	57.2836	26.2951
db4	57.0266	25.8619
db8	57.5173	15.8763

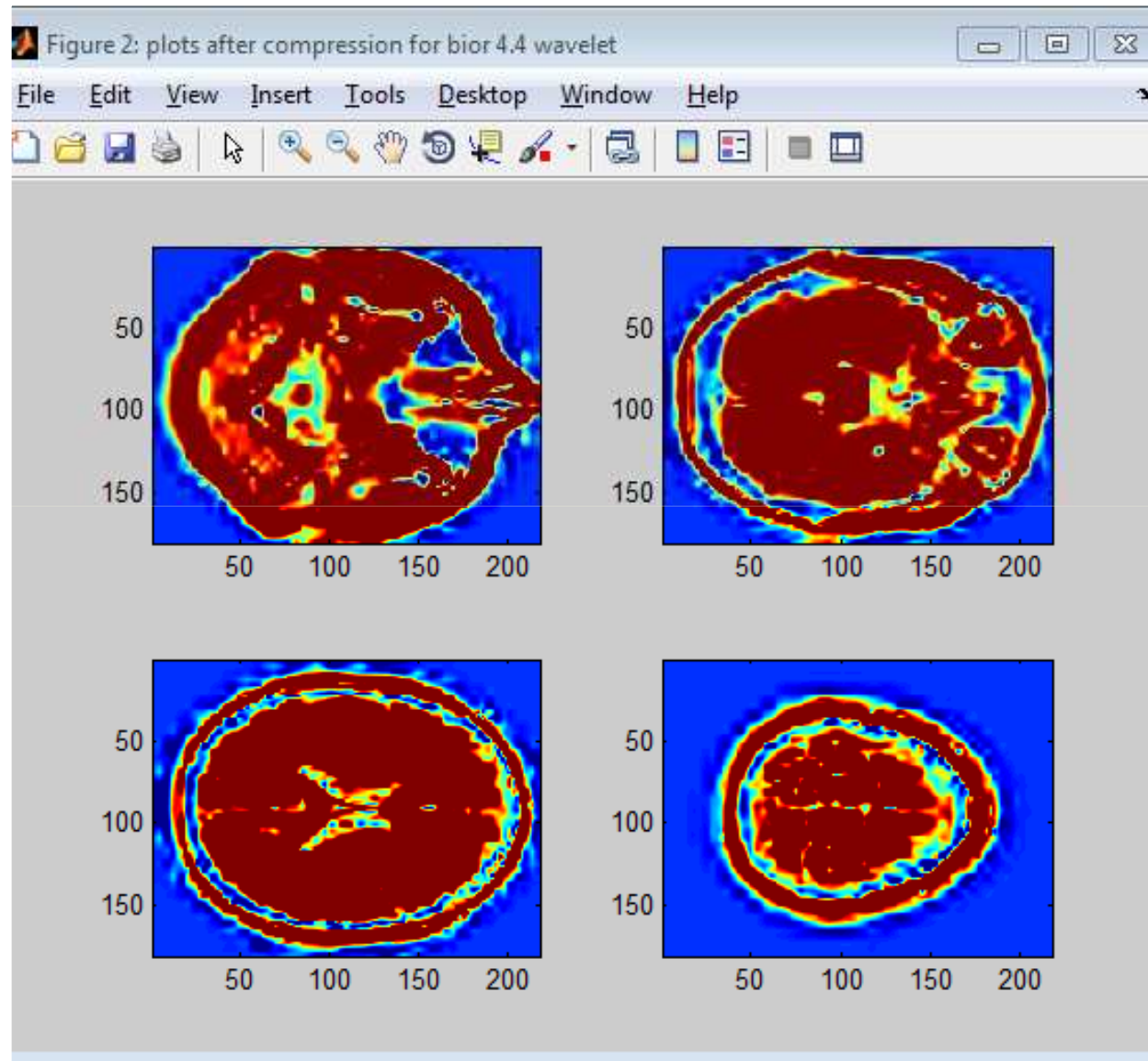
3D data slices with 5% noise



- 3D slices of Reconstructed data after de-noising and compression: using bior 9/7 .
- PSNR=63db
- Compression Ratio=8
- Quantization=0.25



- 3D slices
Reconstructed data after de-noising and compression using bior 9/7
- PSNR=59db
- Compression Ratio=20.
- Quantization=0.75





Thank You