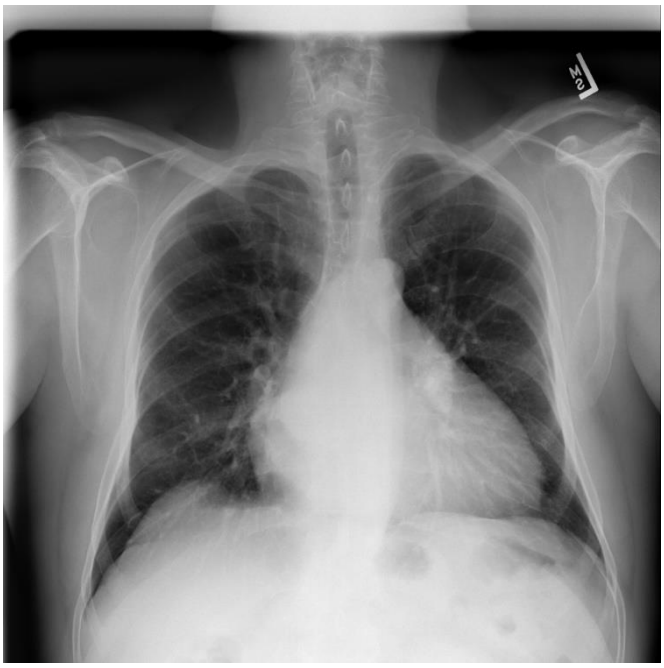
Application of the wavelet transform for the compression of medical images

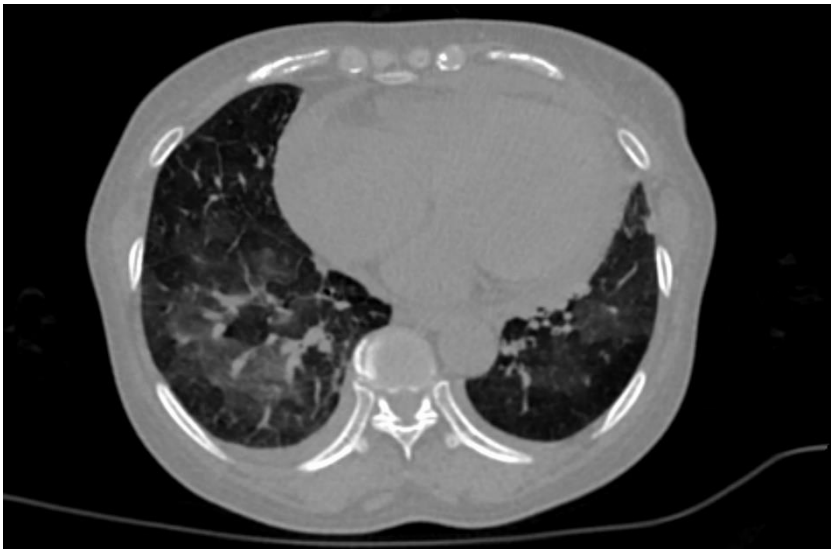
Mert Çinerkan

Original İmages



X-ray image of the lung

Source: https://www.kaggle.com/datasets/nih-chest-xrays/data



CT Image of Covid-19

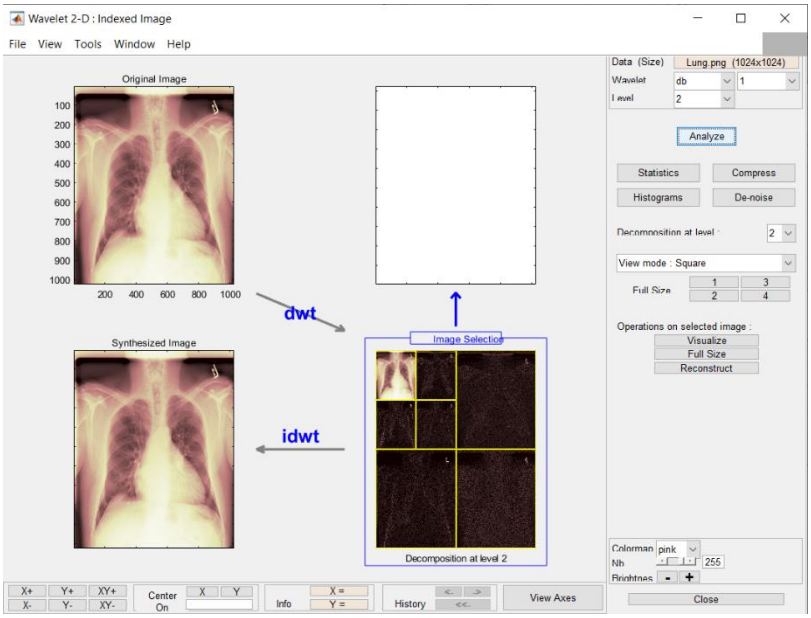
Source: https://www.cancerimagingarchive.net/collection/ct-images-in-covid-19/

Ultrasound of baby body and spine

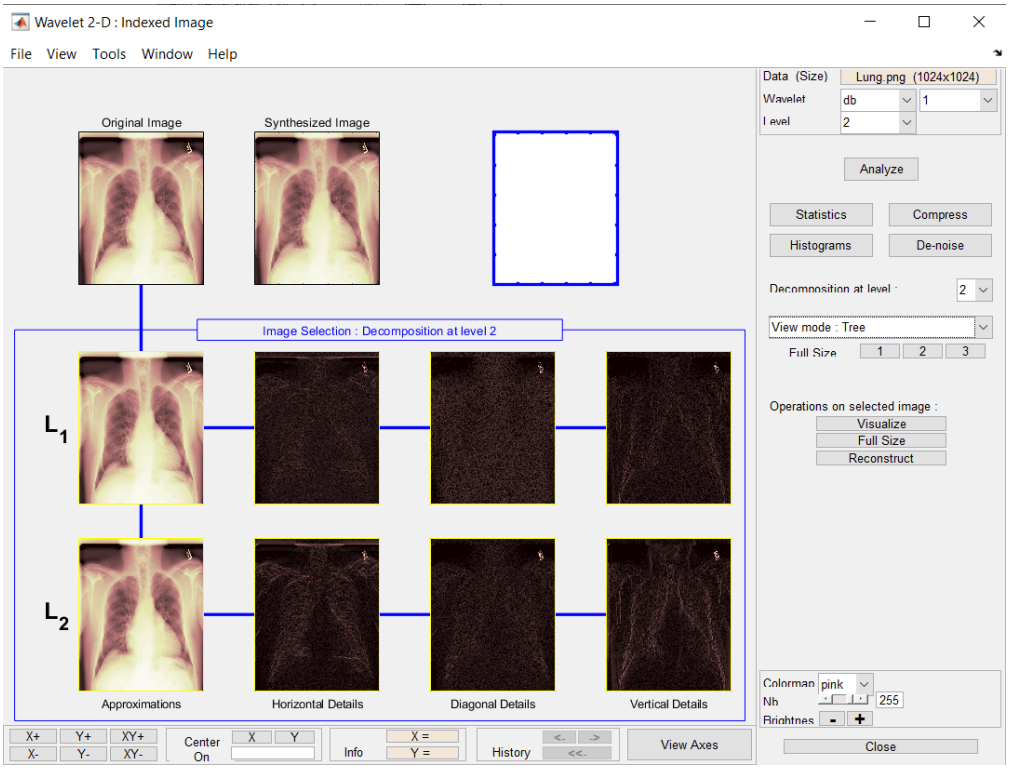
Source: https://www.shutterstock.com/tr/video/clip-1081949861-ultrasound-baby-body-spine-human-embryo-slightly

Using the Wavelet Analyzer toolbox (2-D Wavelet), process the X-ray image of the lung using the following wavelets

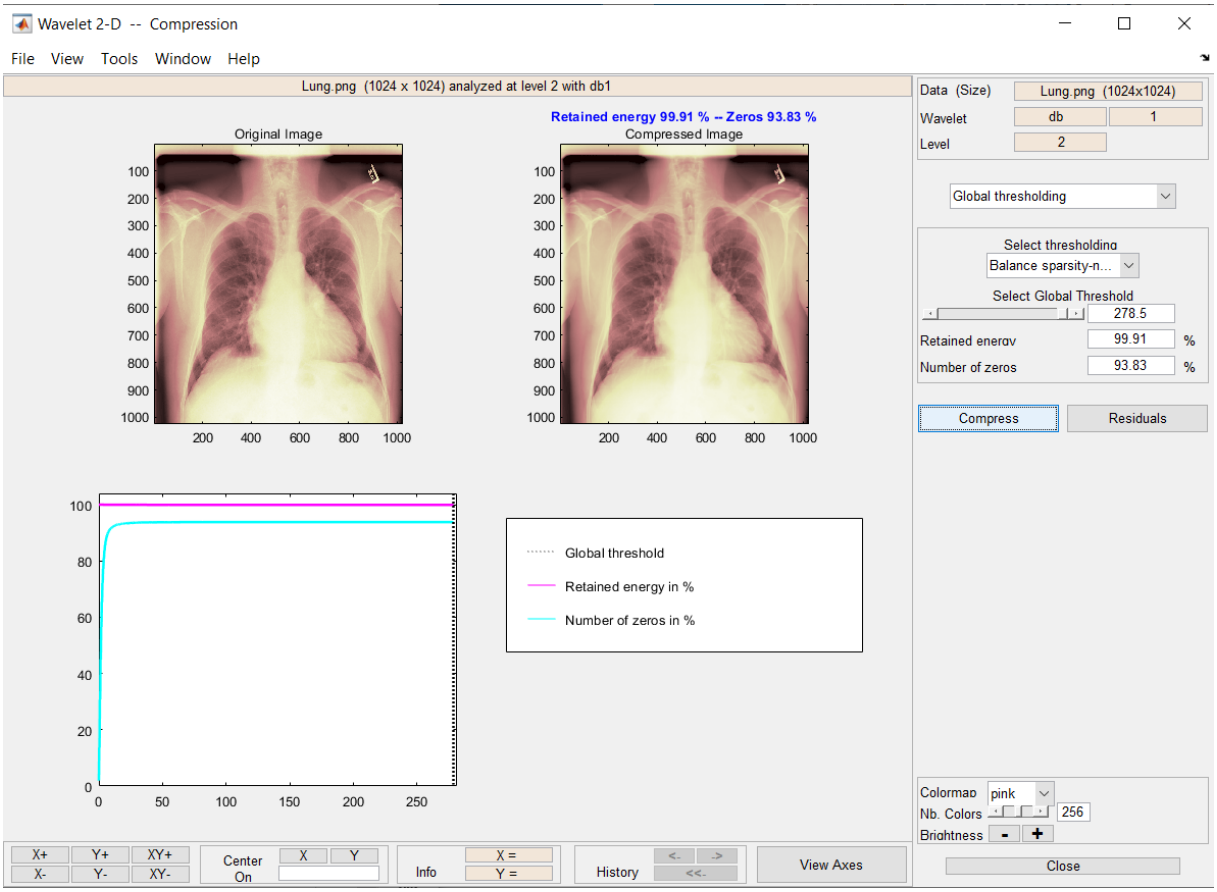
A. db 1 level 2



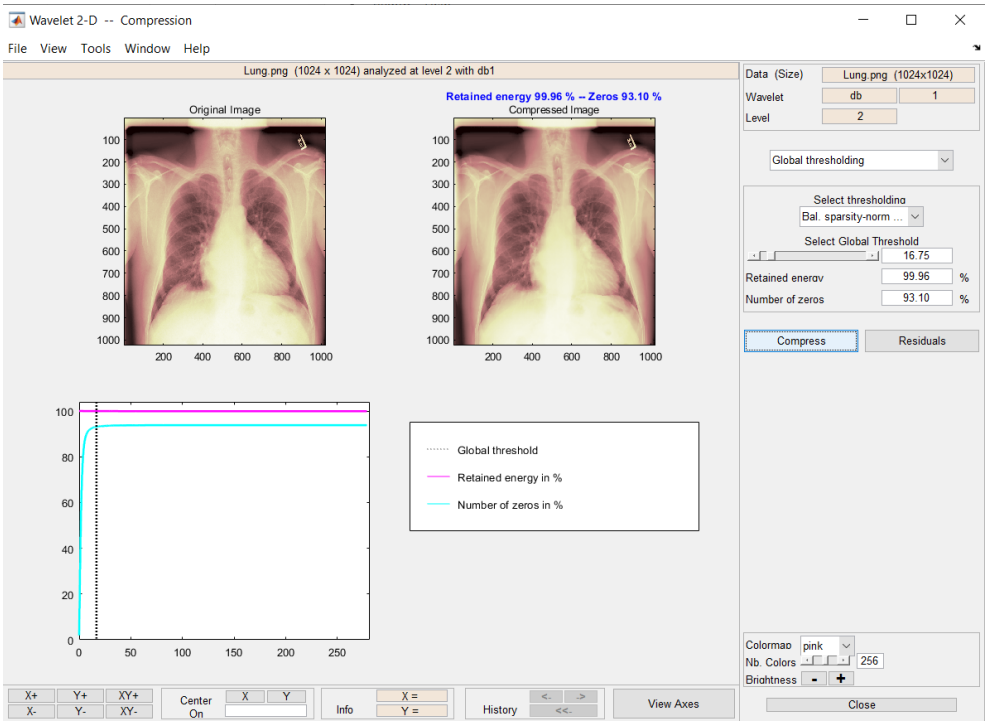
Display the decomposition tree - details and approximations at successive levels of decomposition.



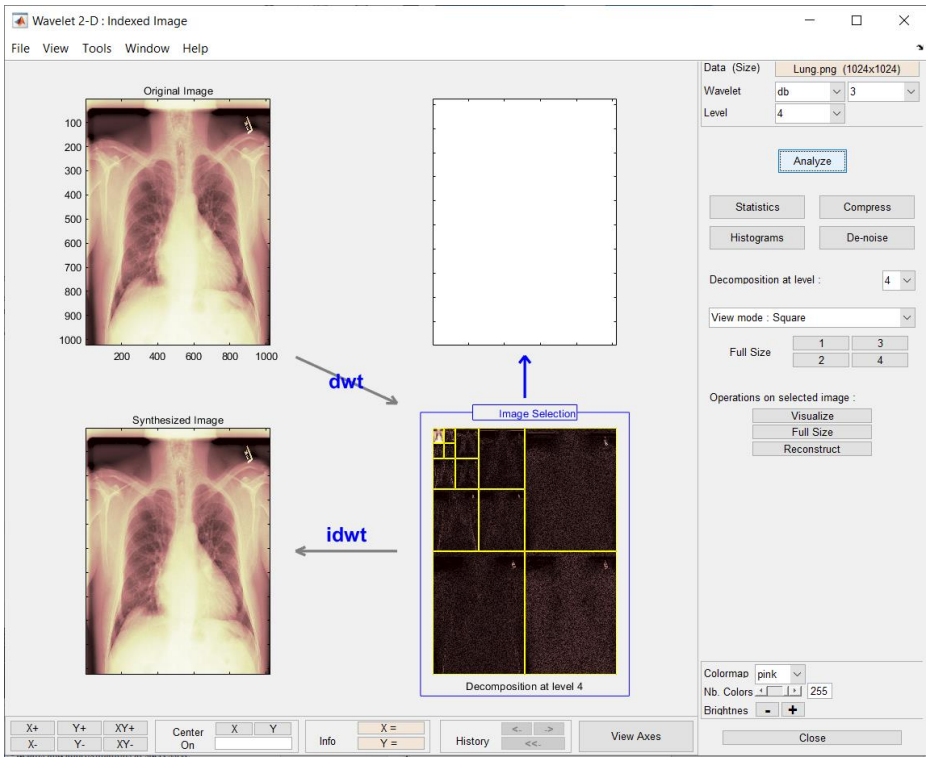
Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



B. db 3 level 4



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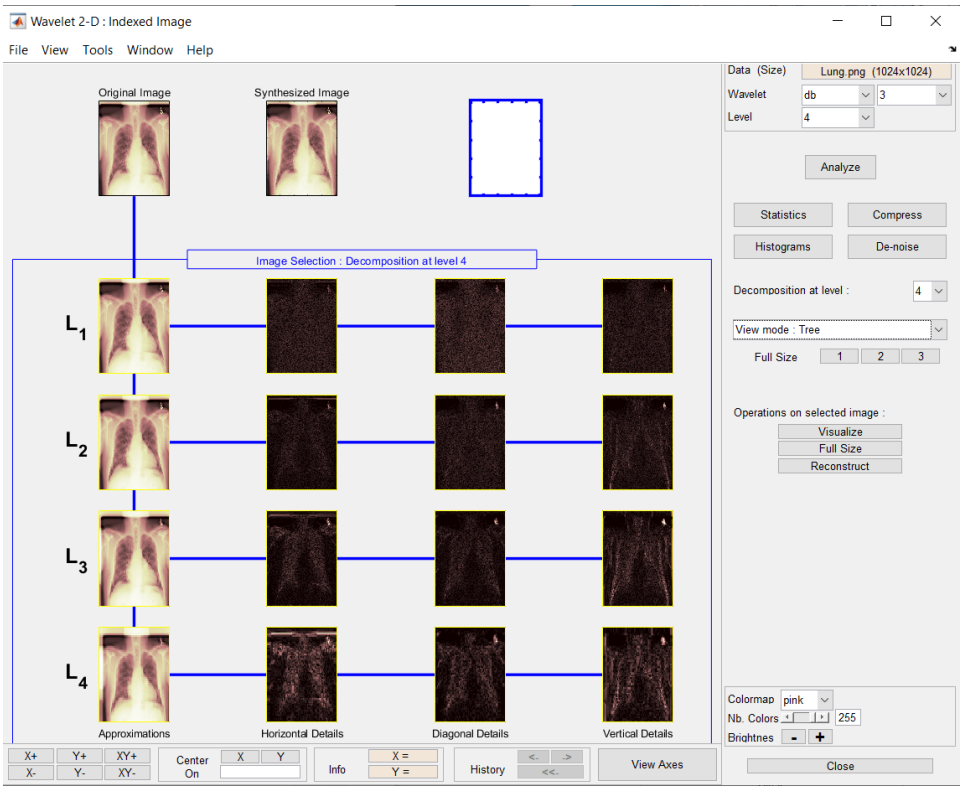
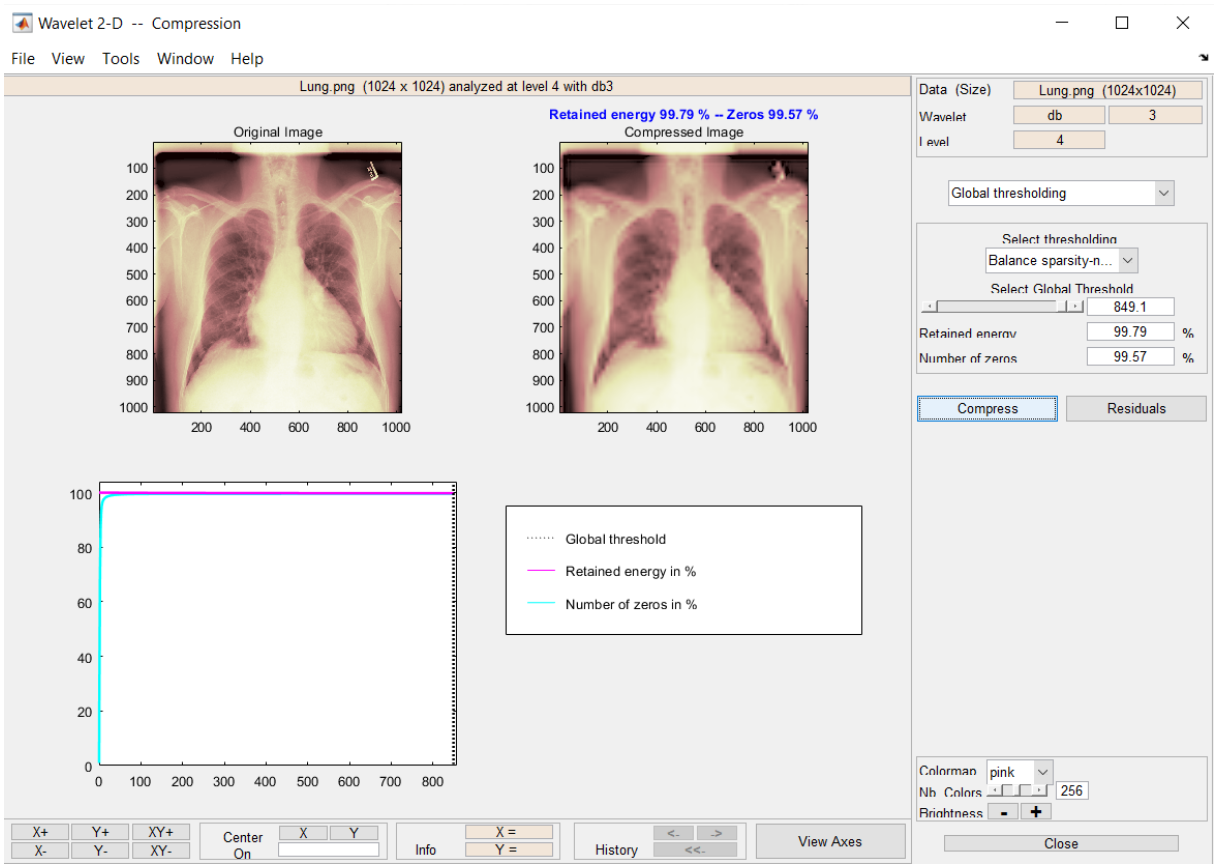
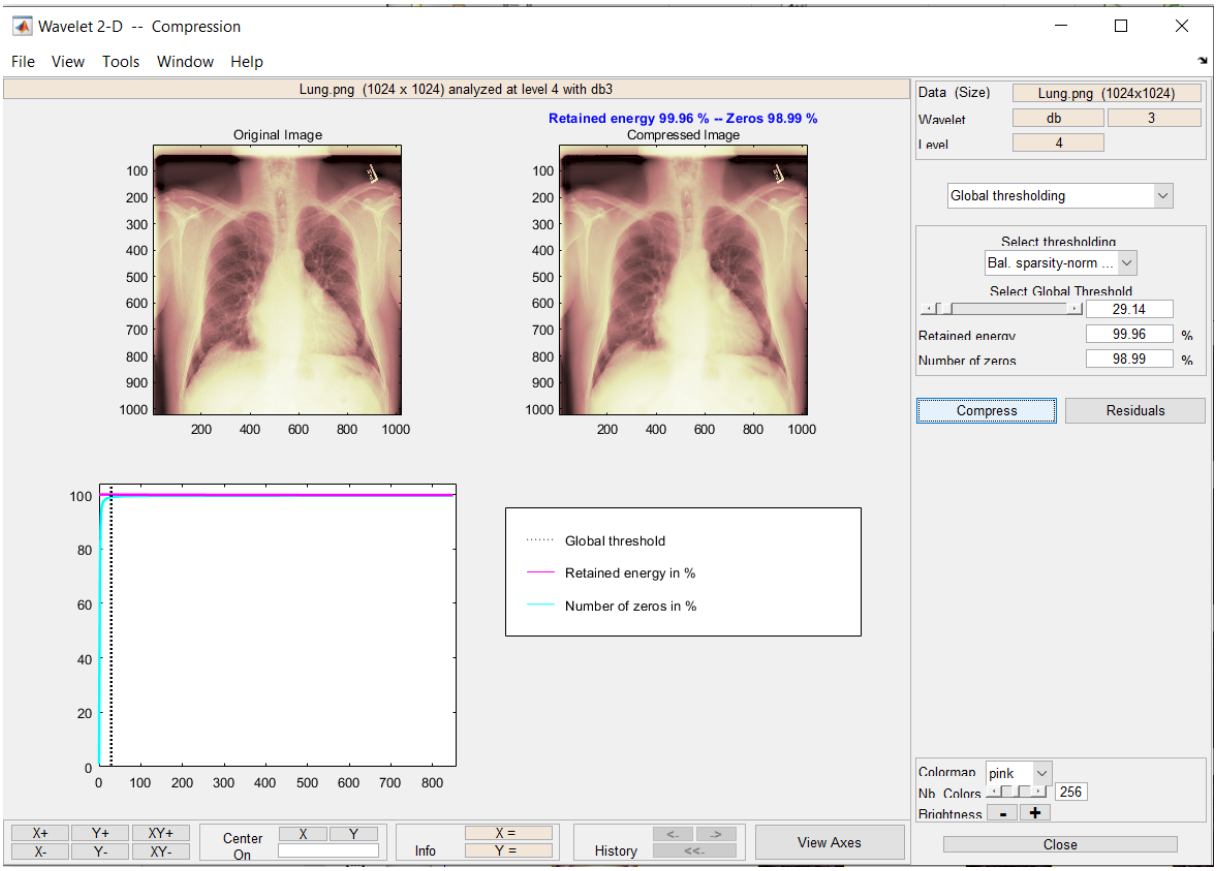


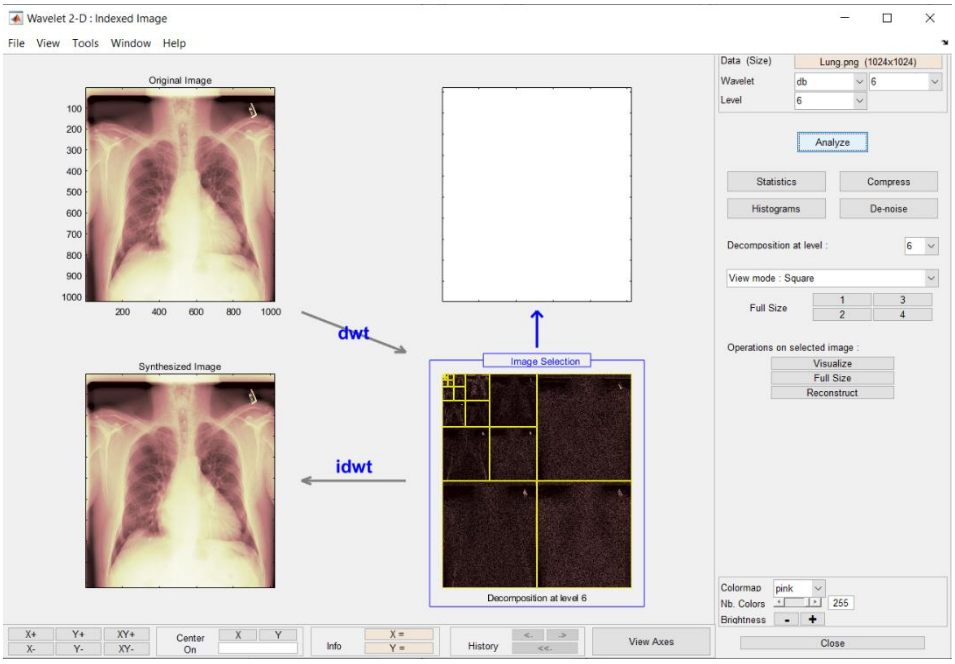
Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



C. db 6 level 6



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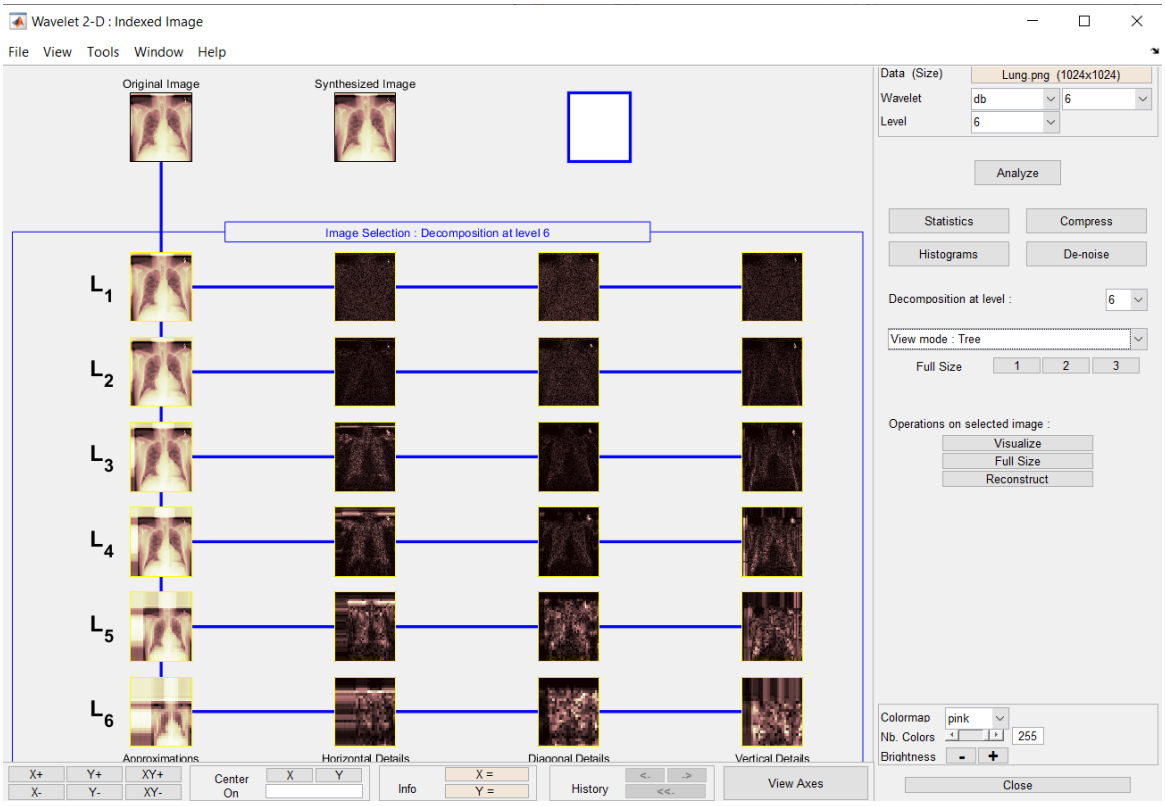
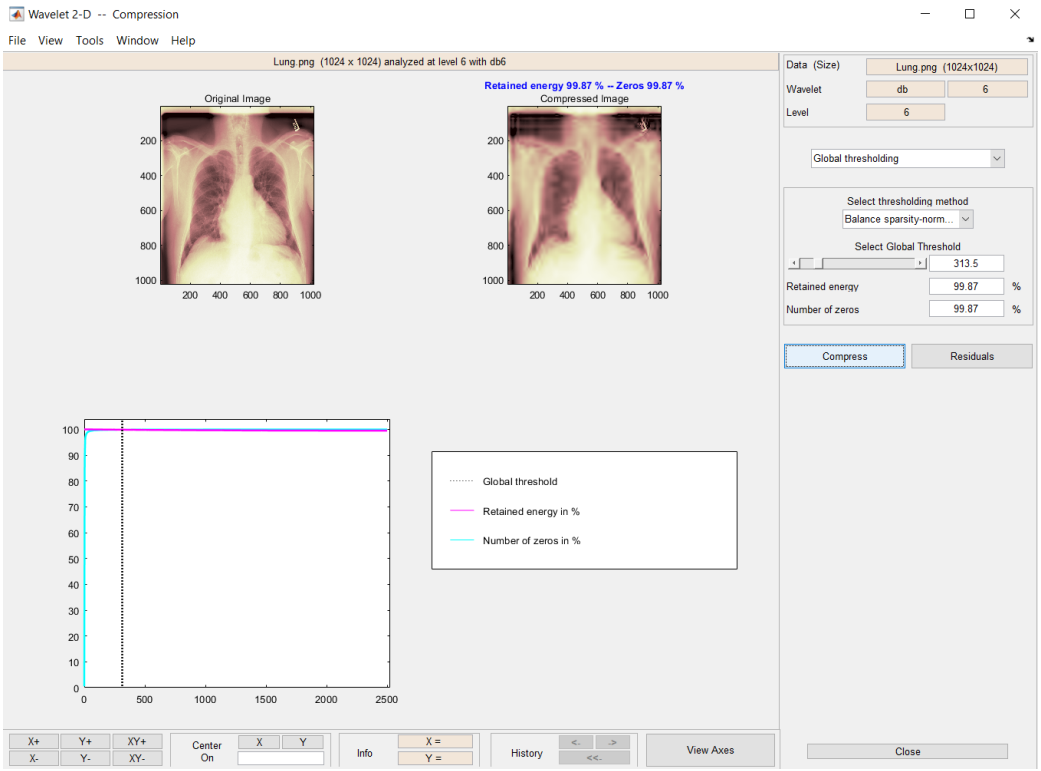
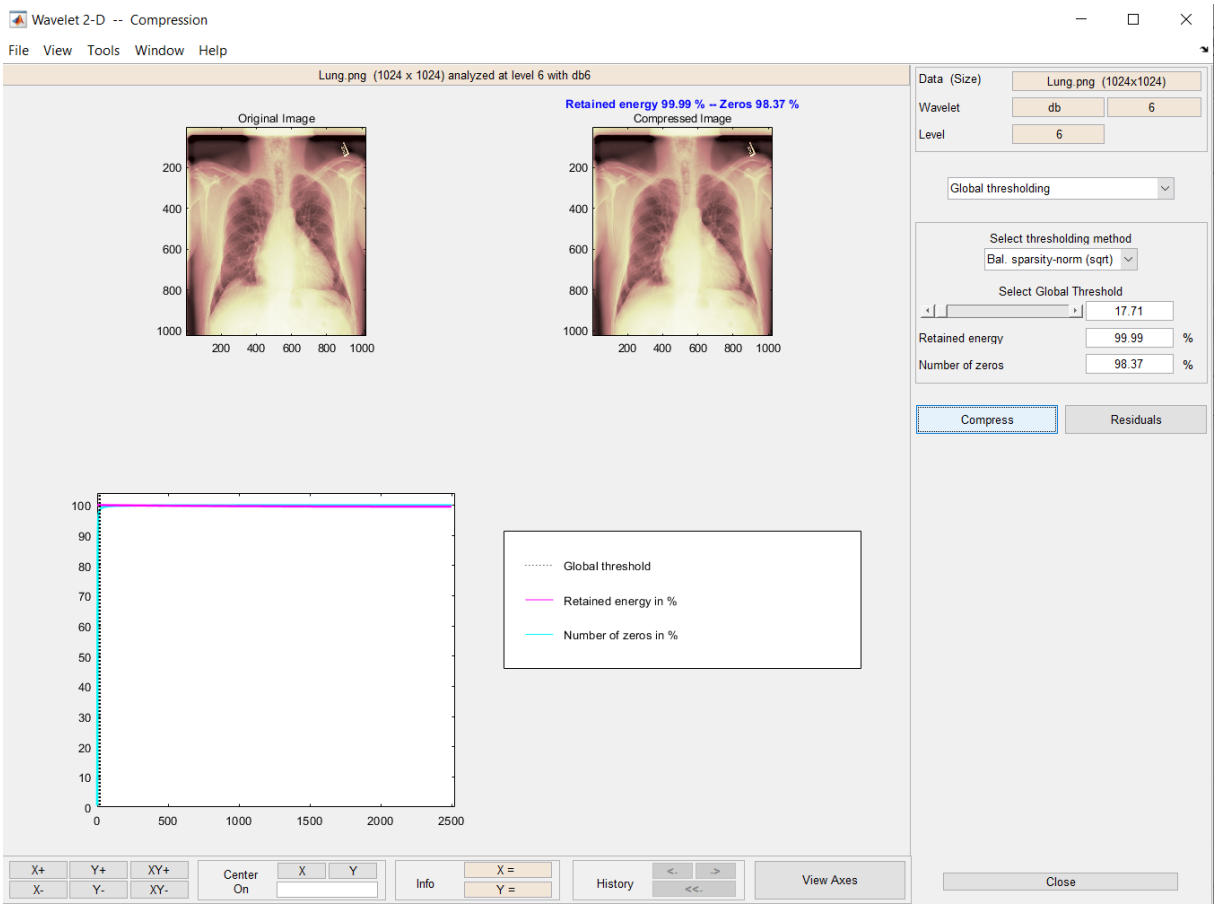


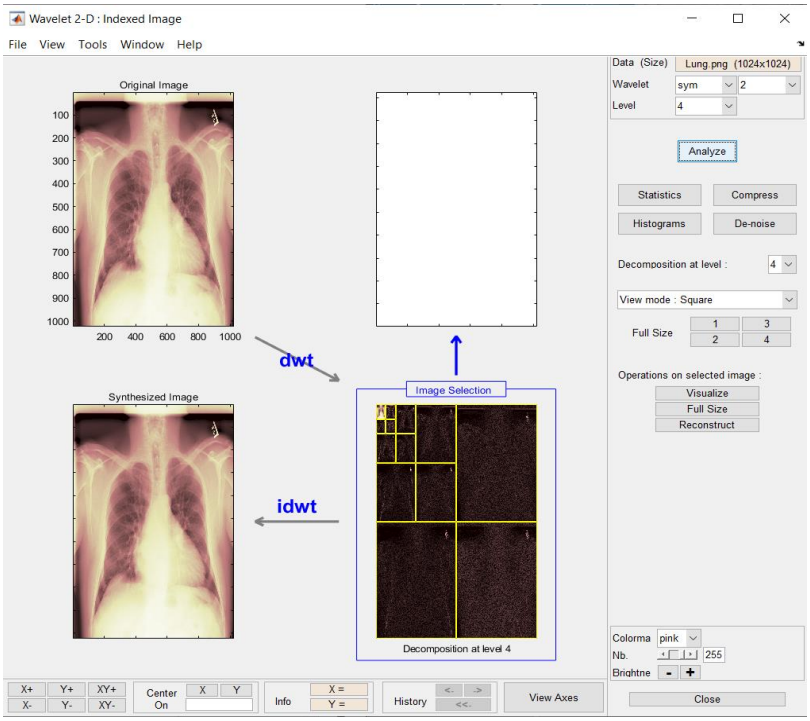
Compress the image using global thresholding with the adopted threshold sparsity-norm



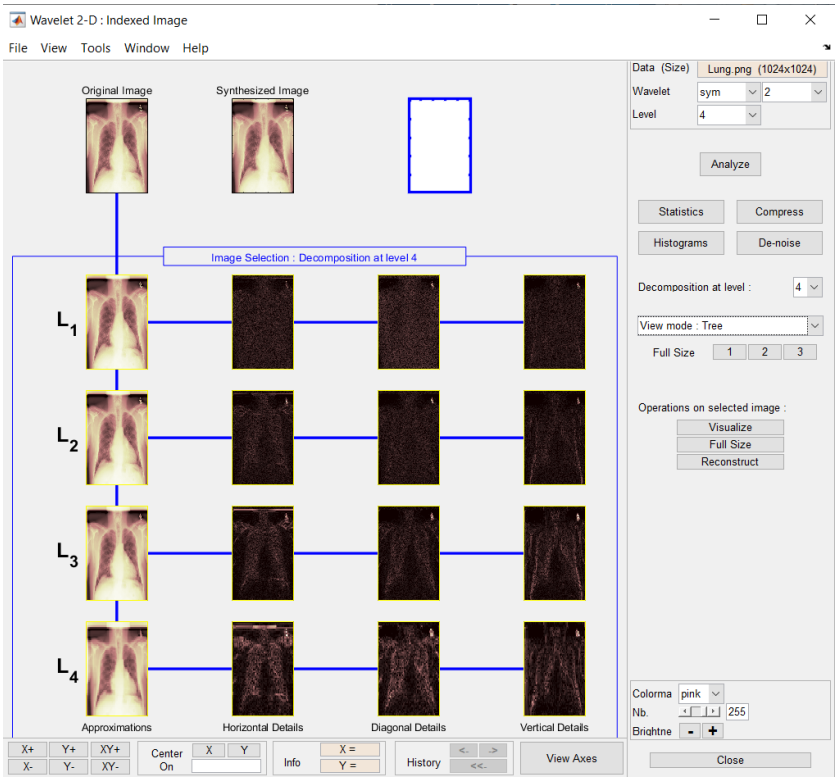
compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



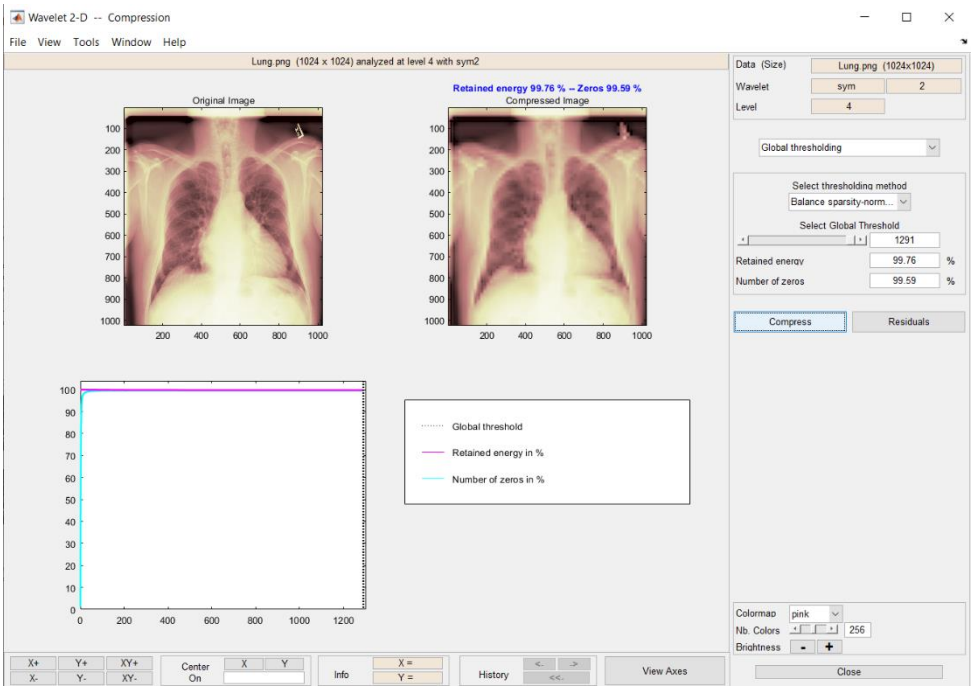
D. sym 2 level 4



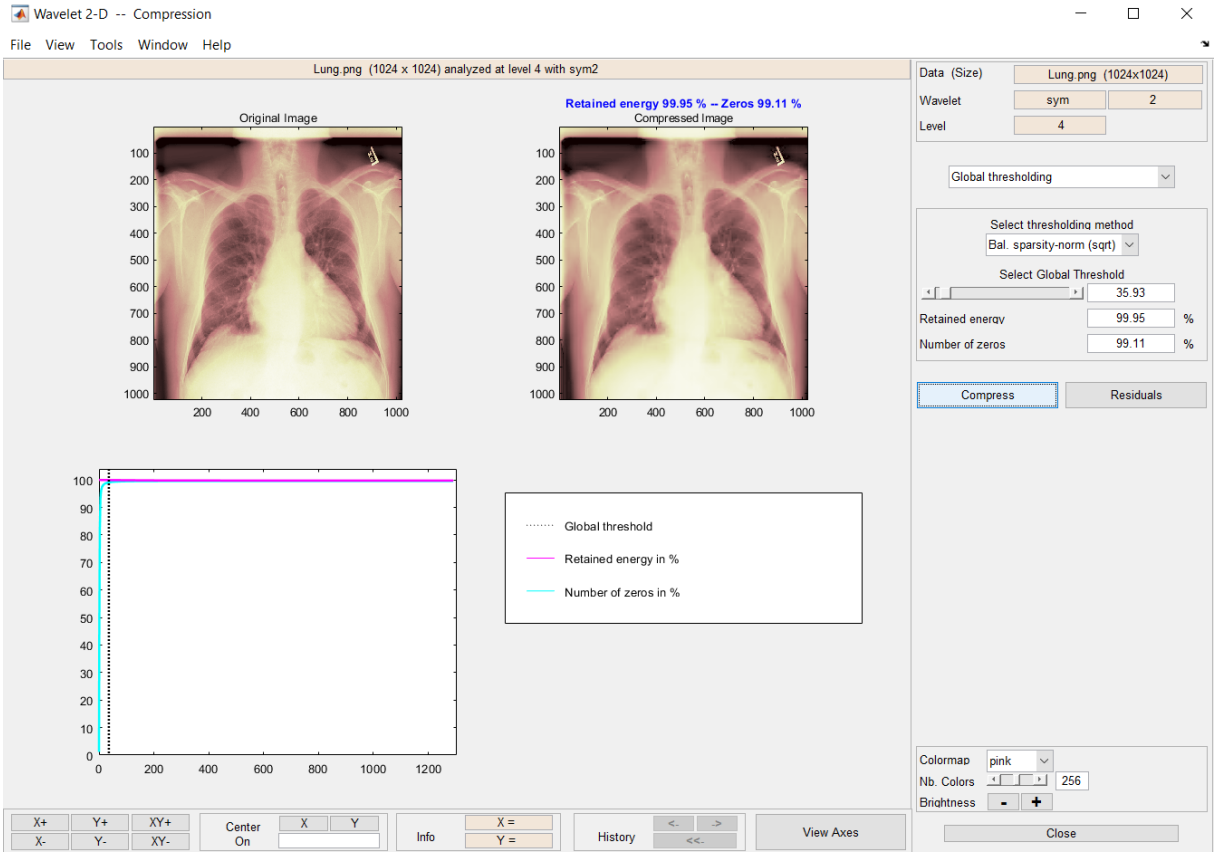
display the decomposition tree - details and approximations at successive levels of decomposition.



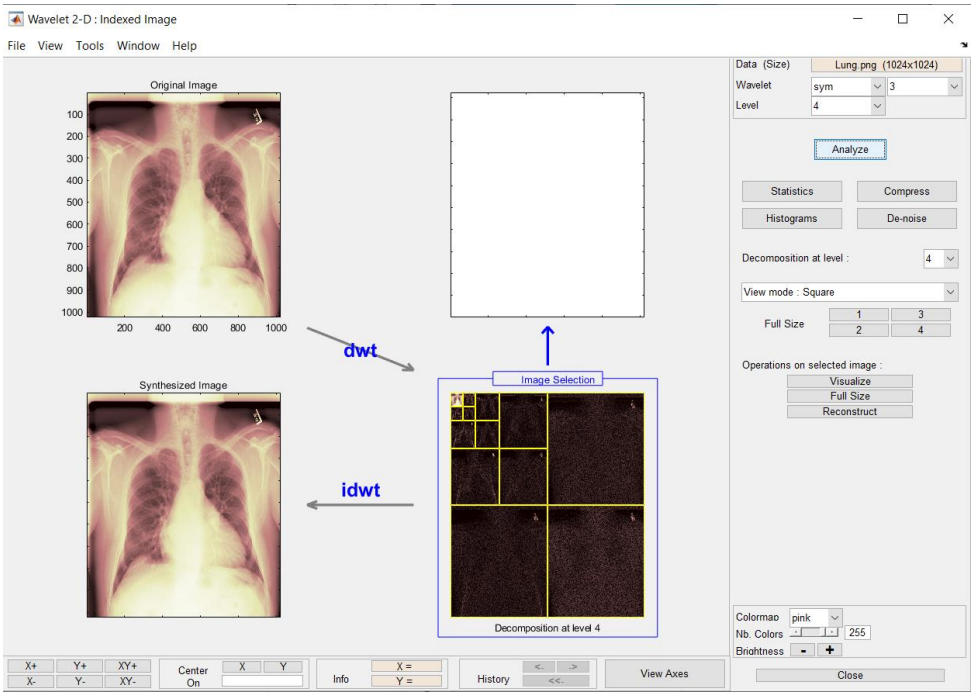
compress the image using global thresholding with the adopted threshold Sparsity-norm



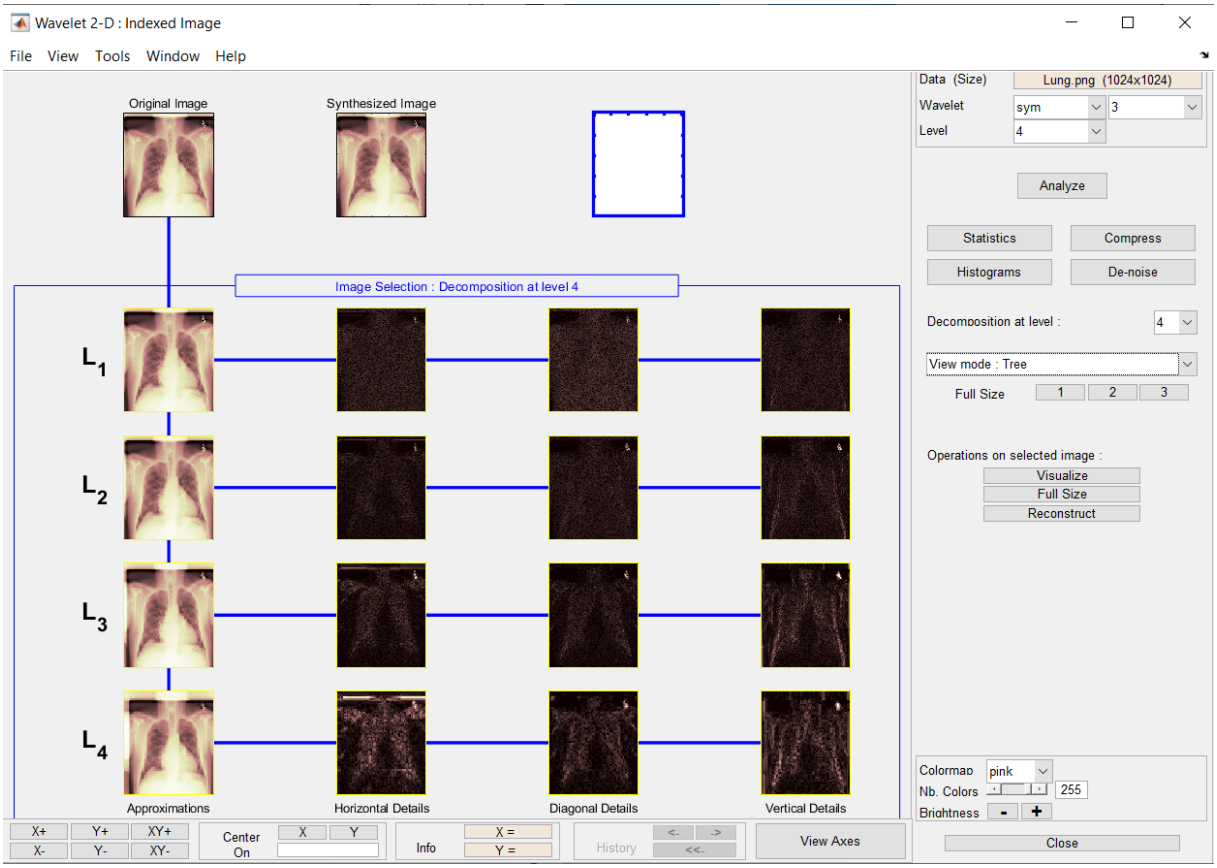
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



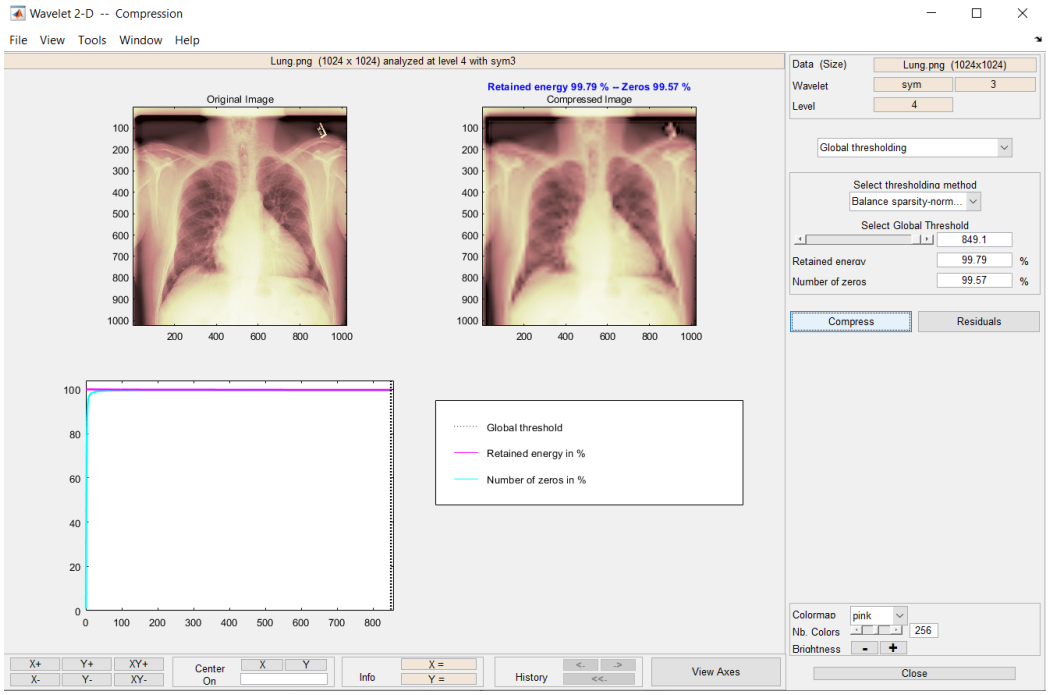
E. sym 3 level 4



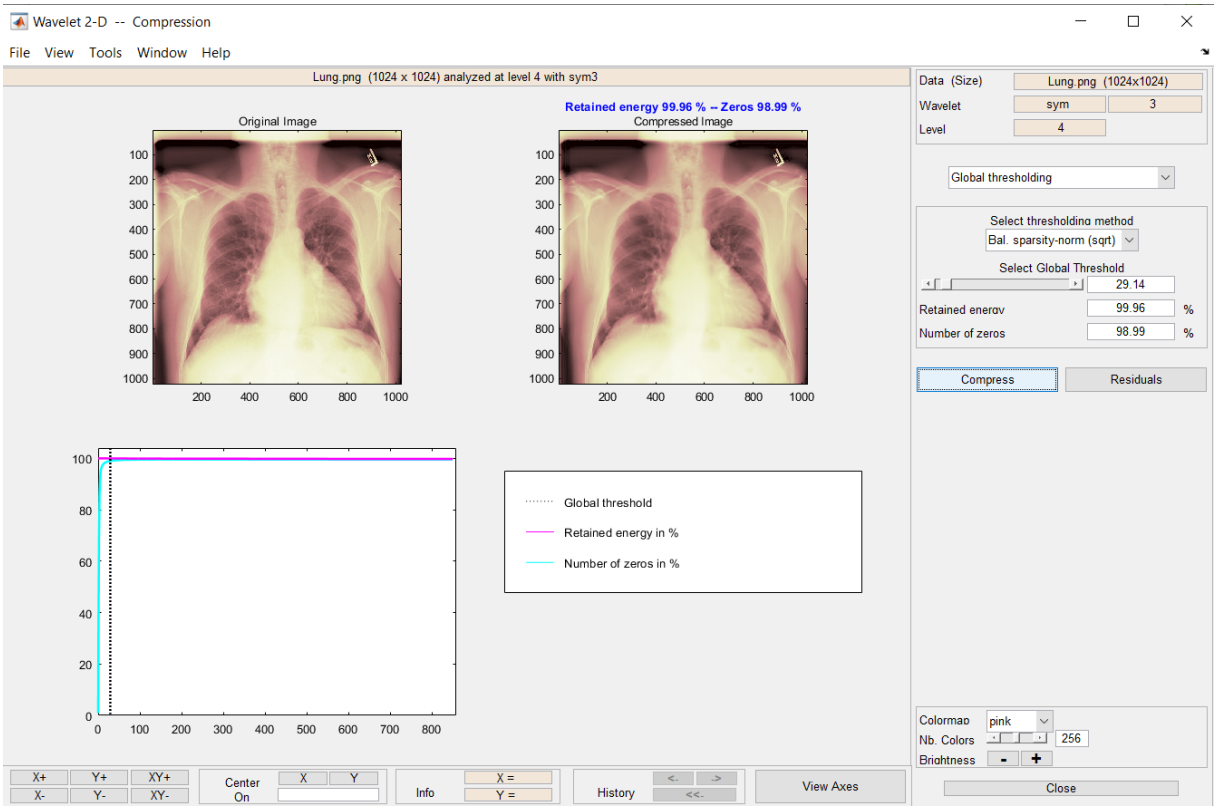
Display the decomposition tree - details and approximations at successive levels of decomposition.



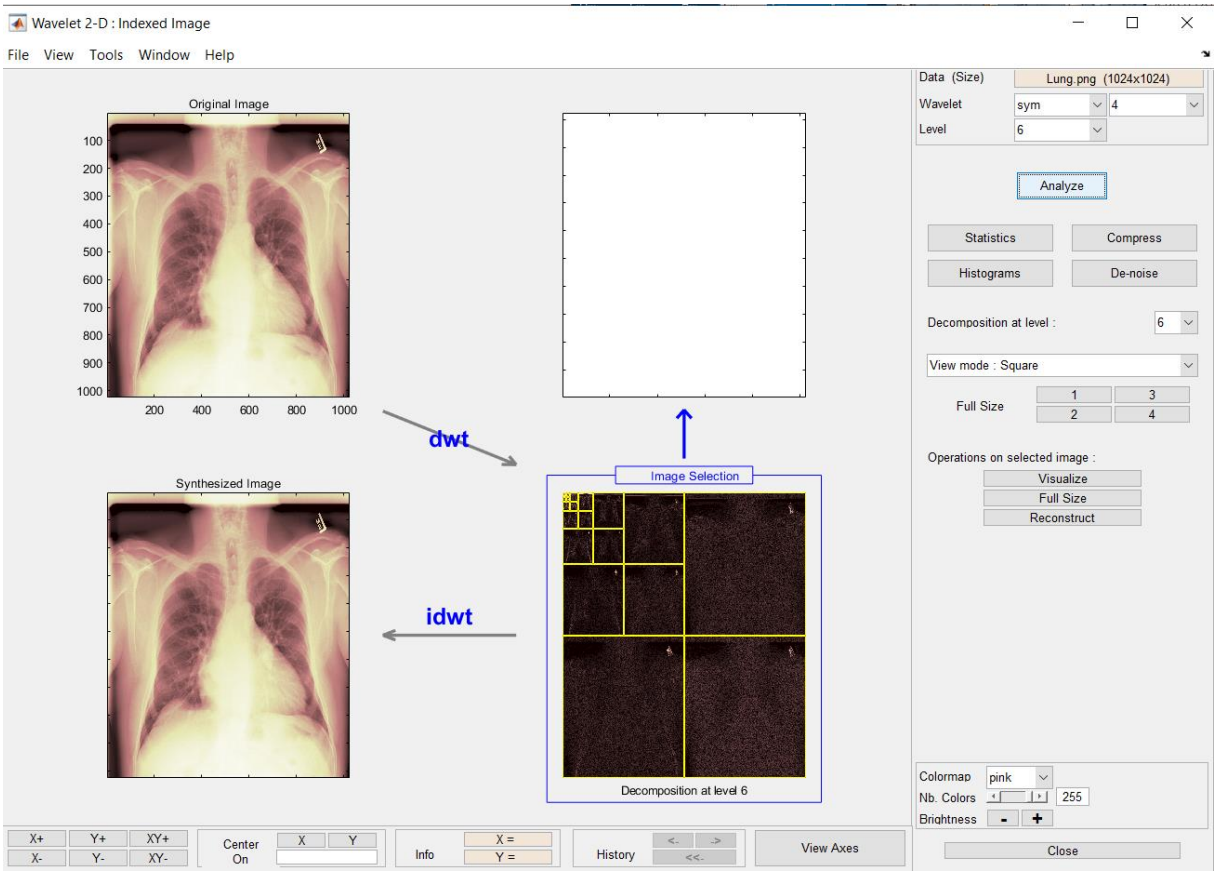
Compress the image using global thresholding with the adopted threshold sparsity-norm



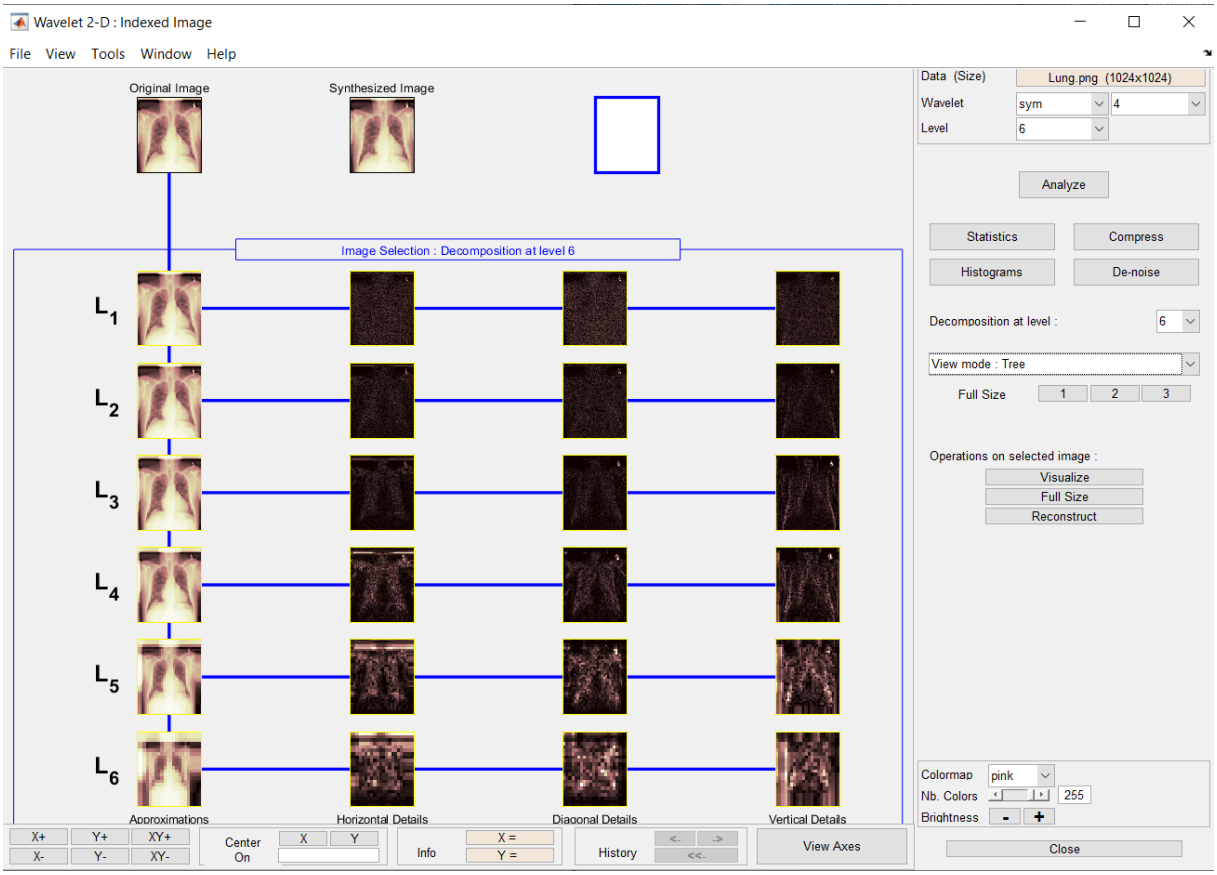
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



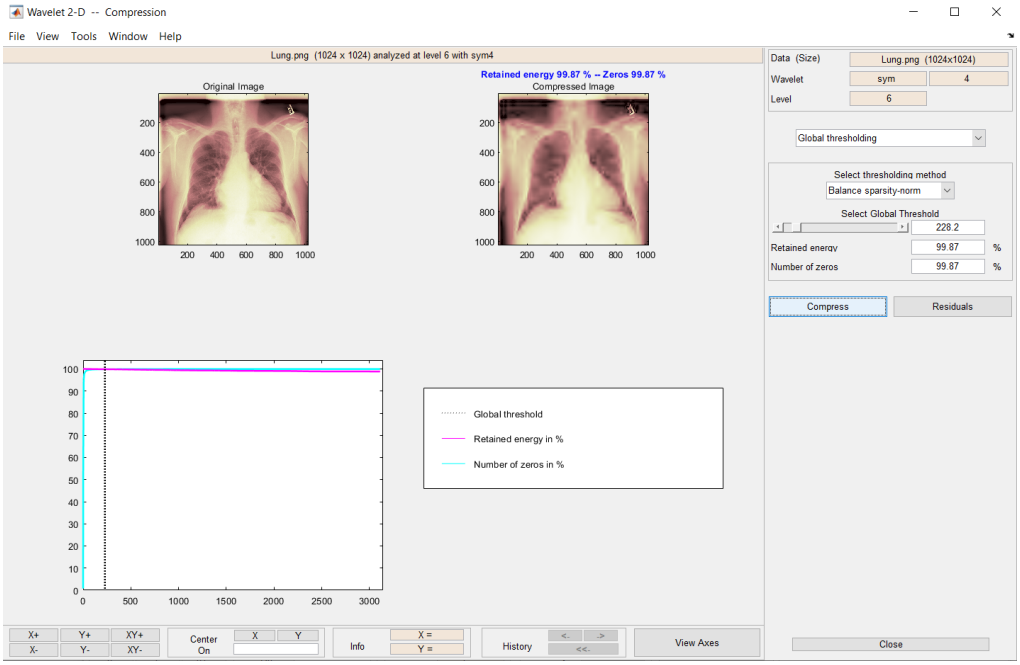
F. sym 4 level 6



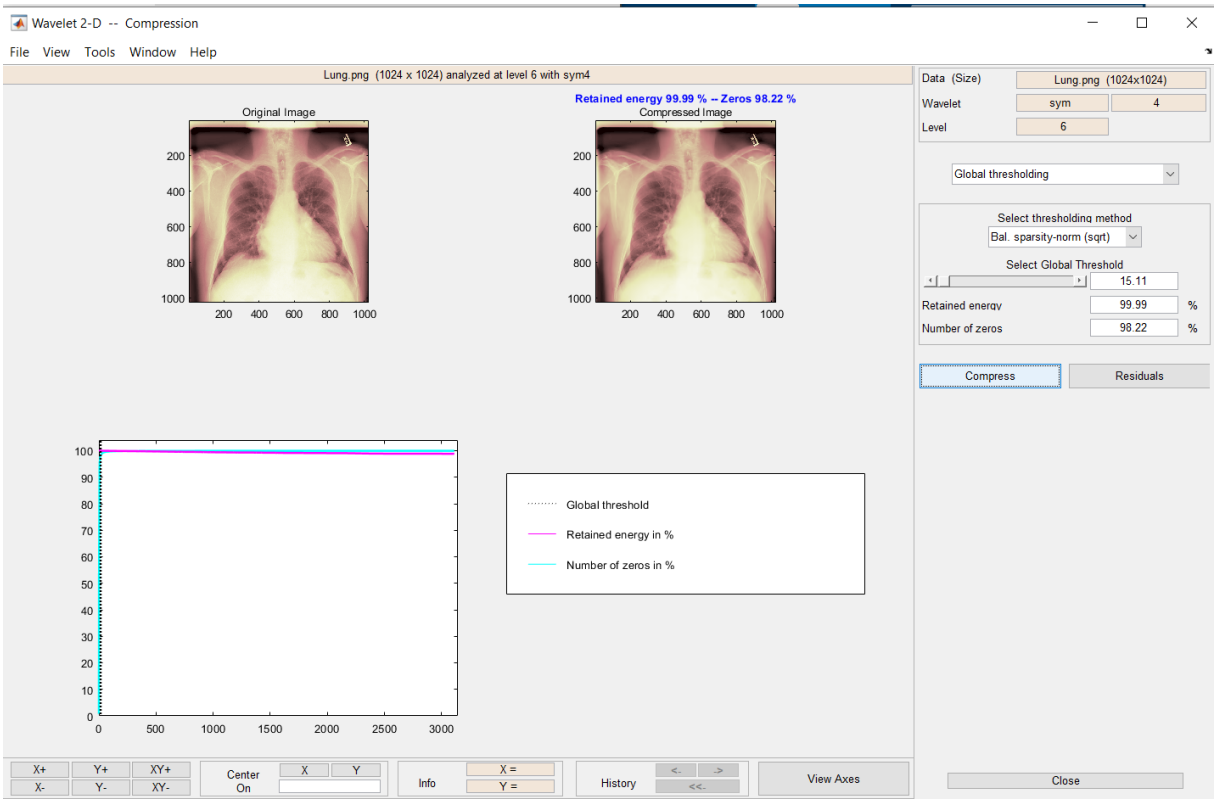
Display the decomposition tree - details and approximations at successive levels of decomposition.



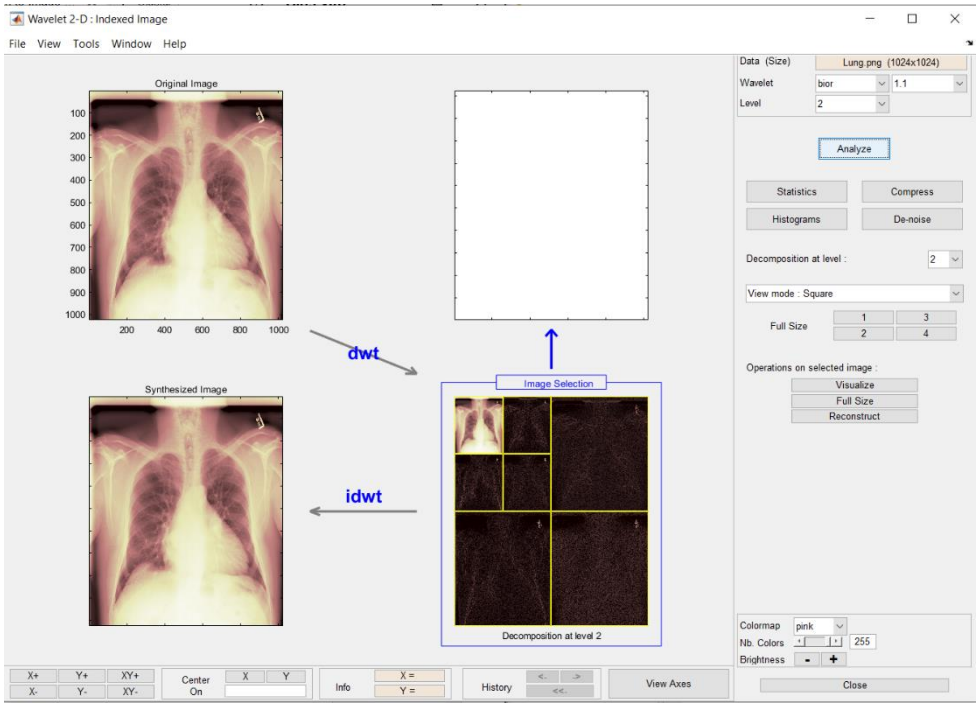
Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



G. bior 1.1: level 2



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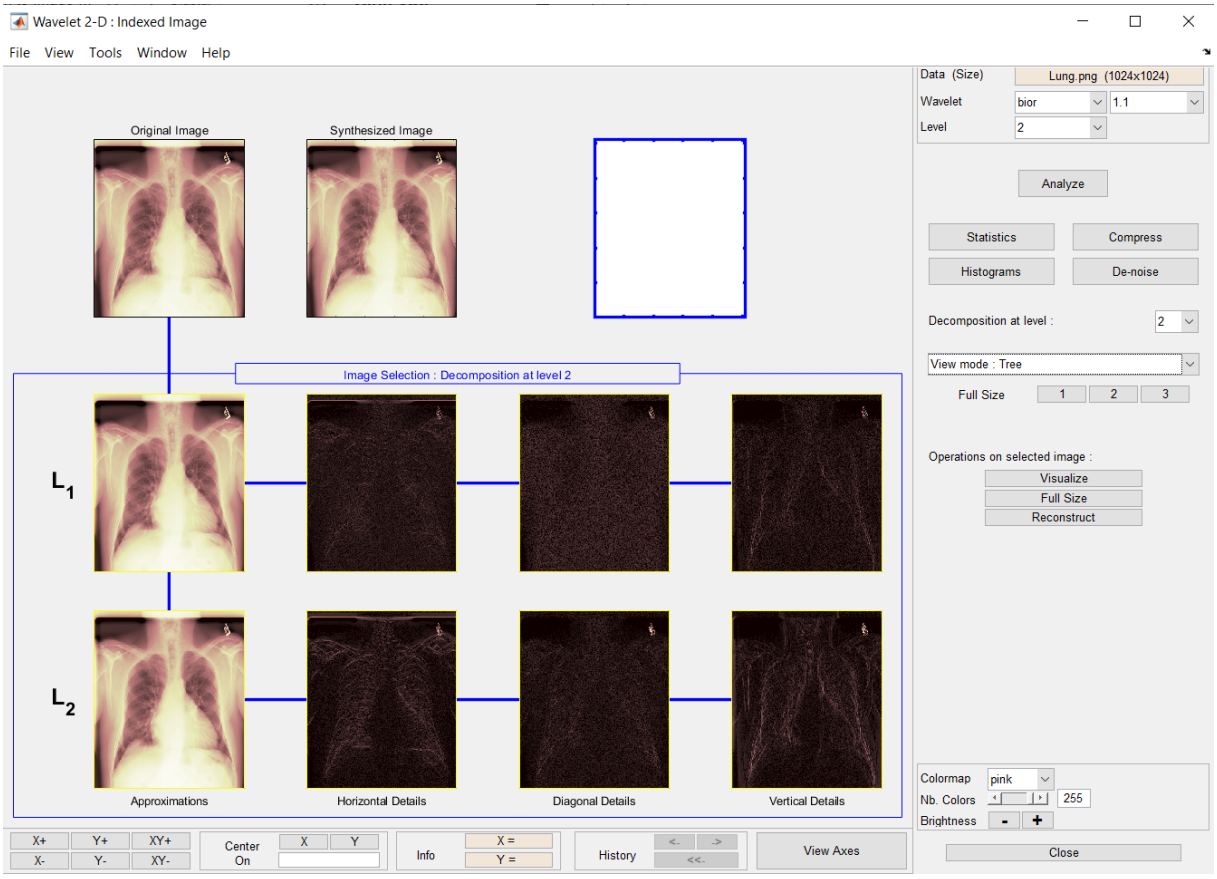
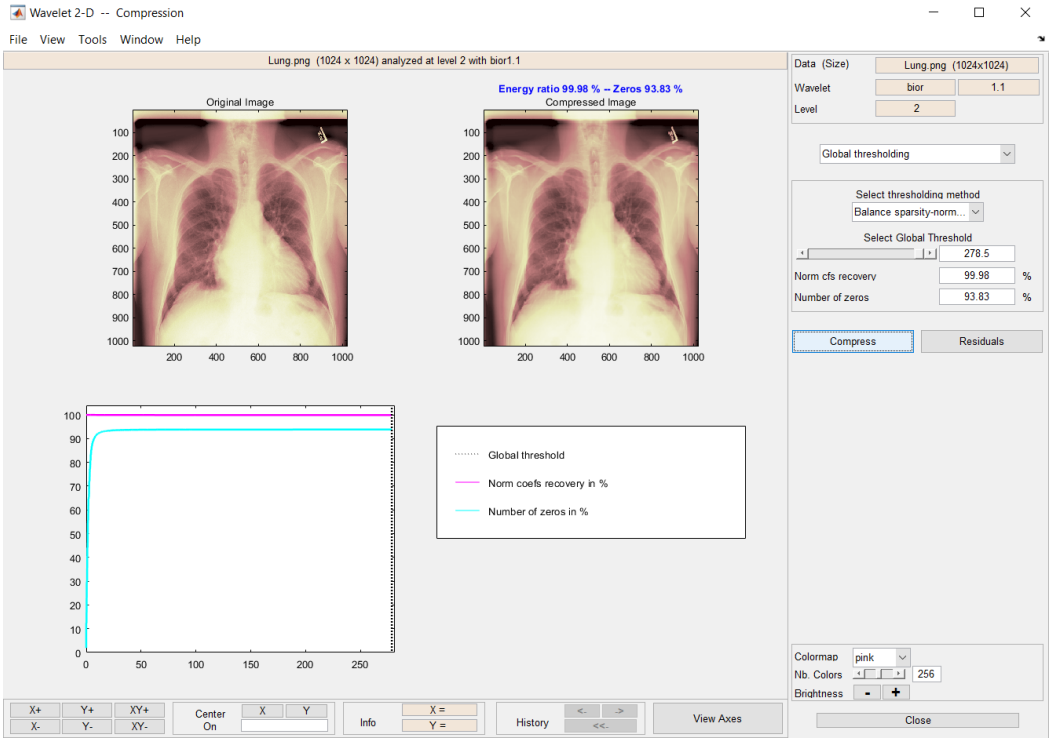
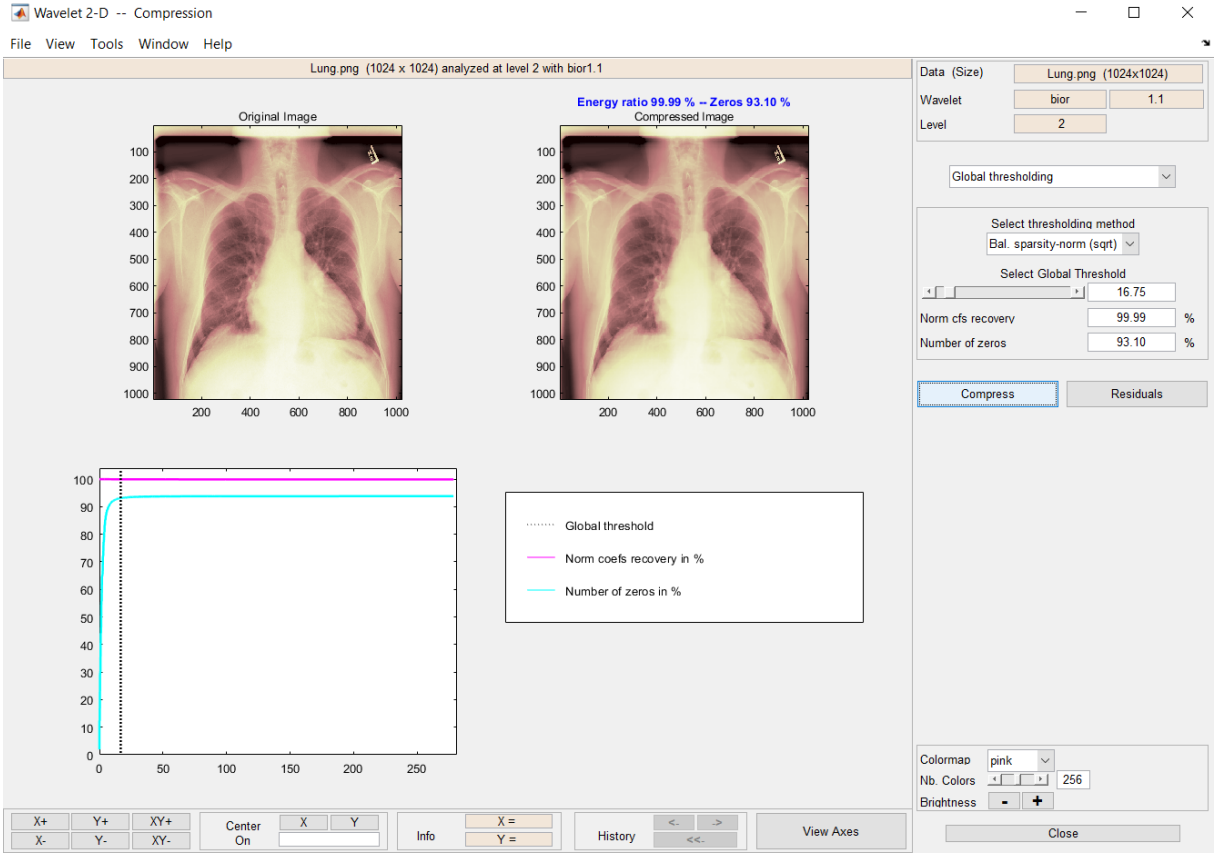


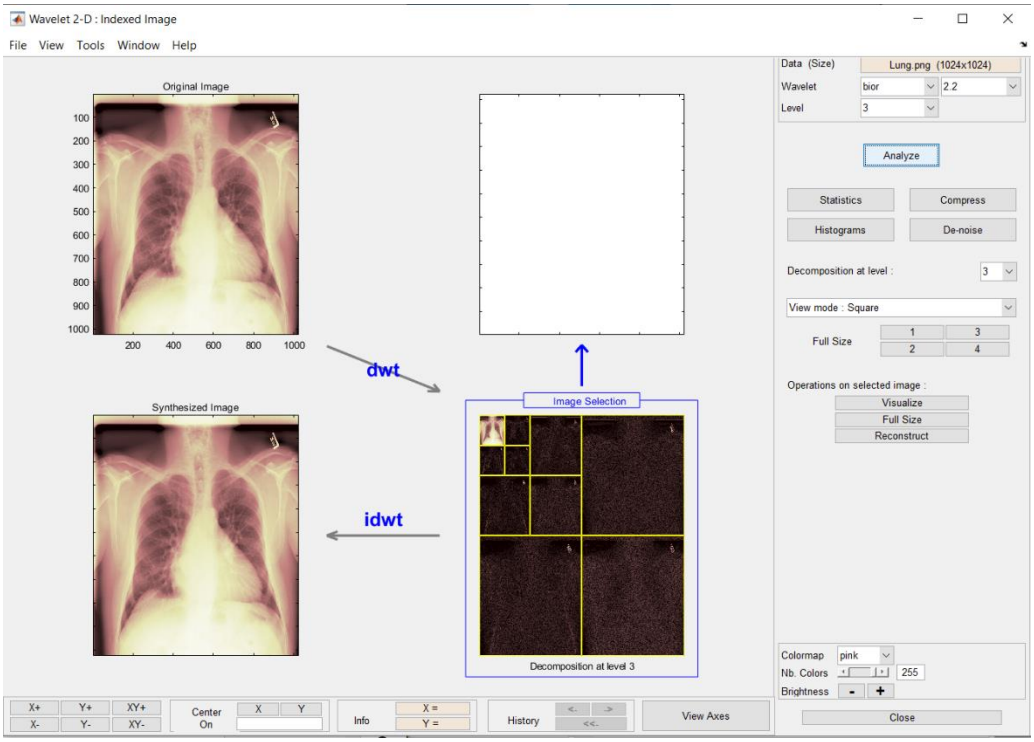
Compress the image using global thresholding with the adopted threshold sparsity-norm,



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



H. bior 2.2: level 3



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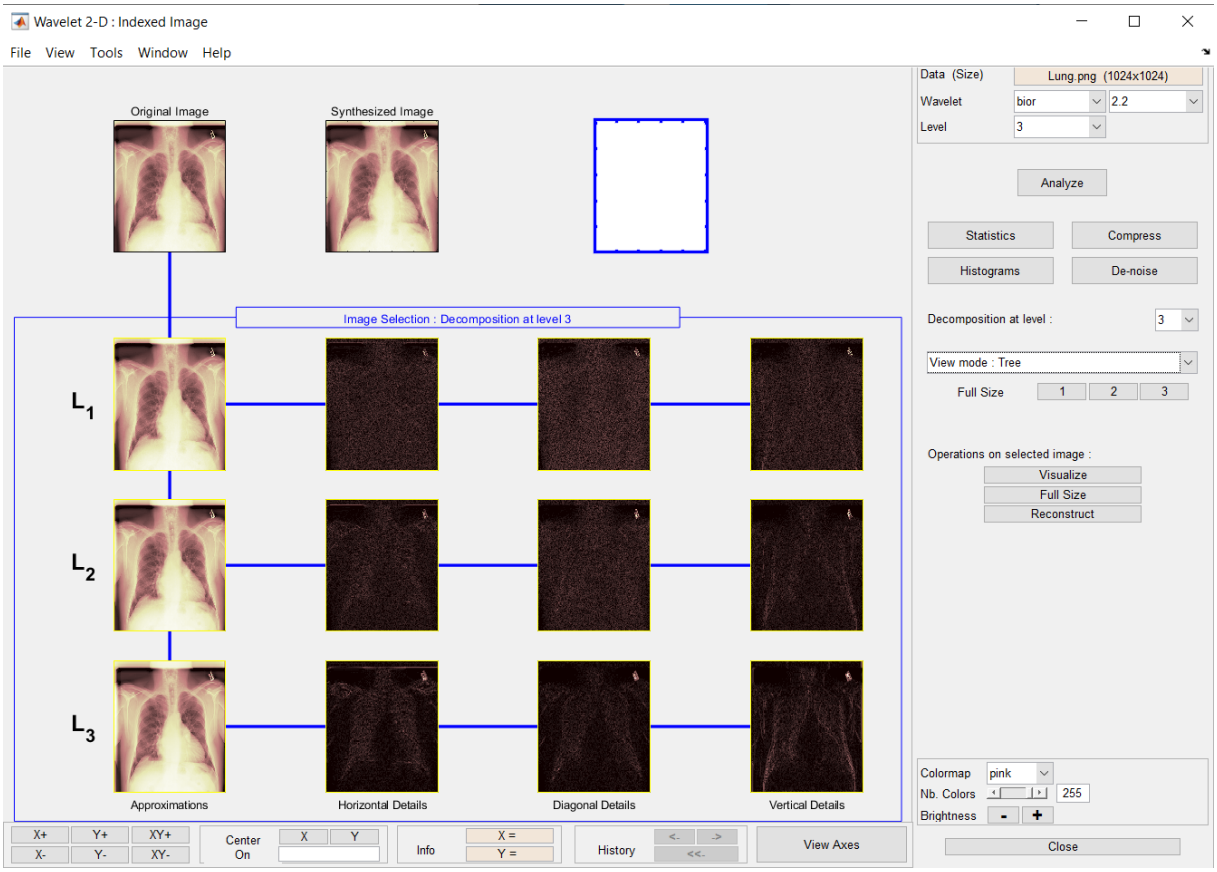
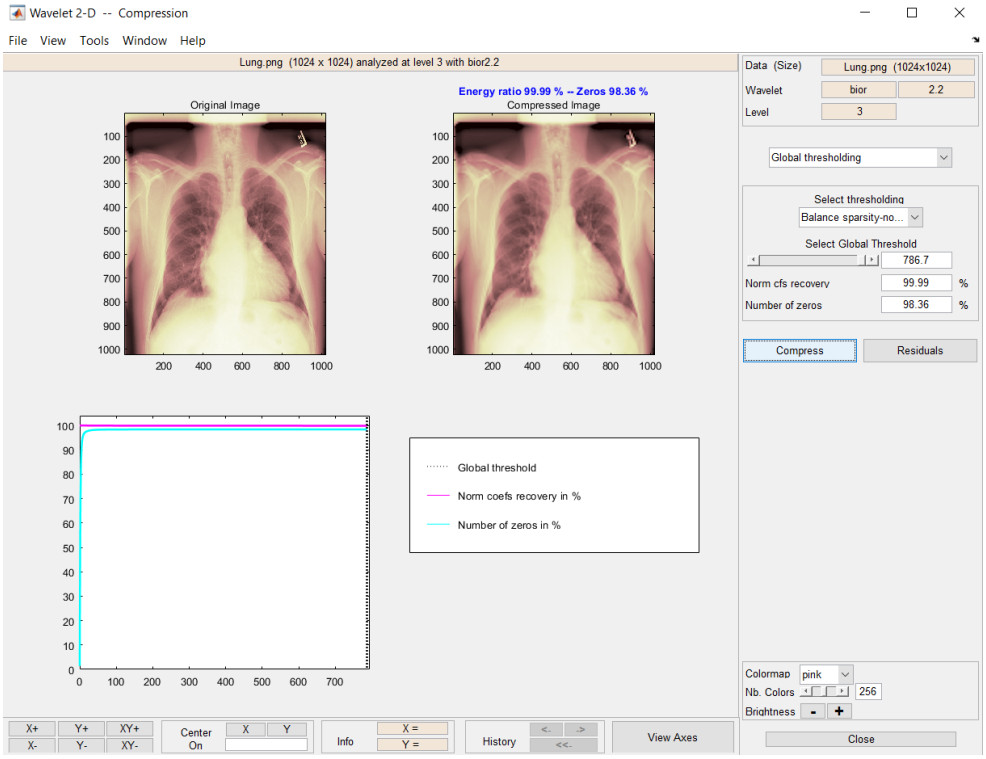
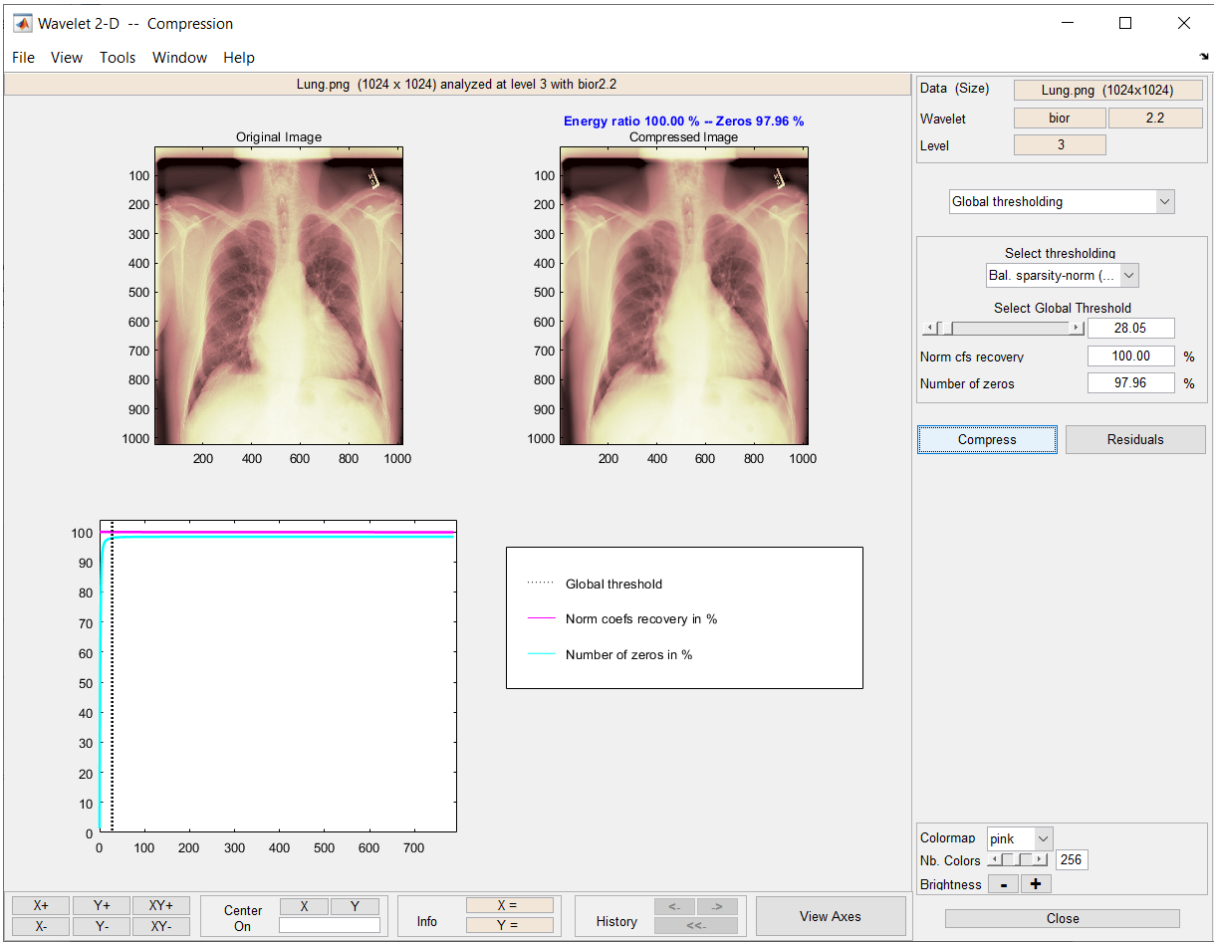


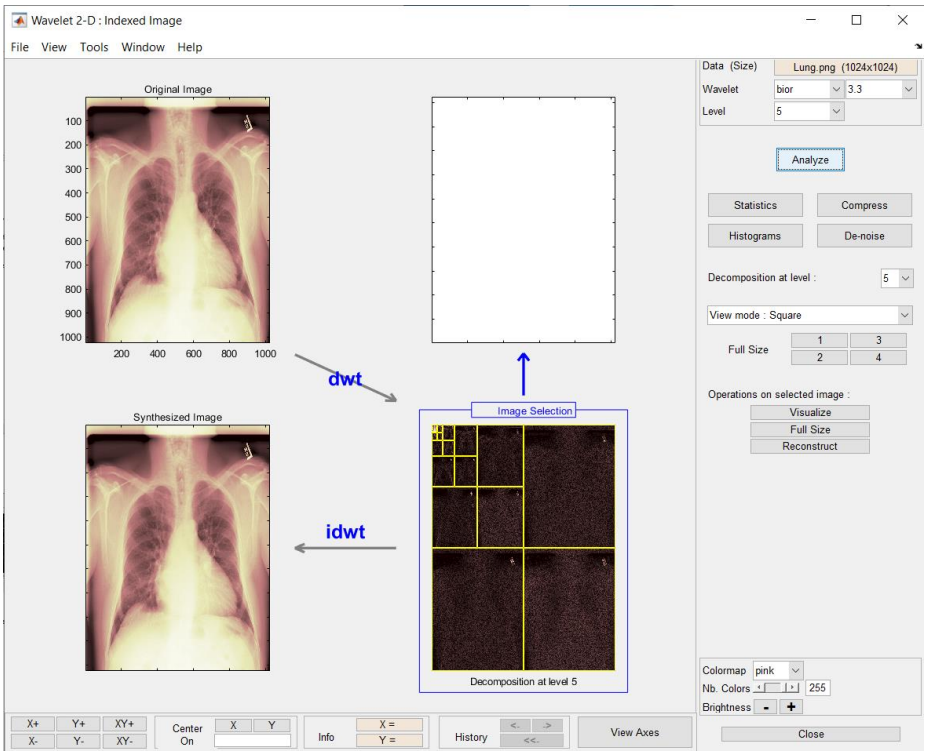
Compress the image using global thresholding with the adopted threshold sparsity-norm,



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



I.bior 3.3: level 5



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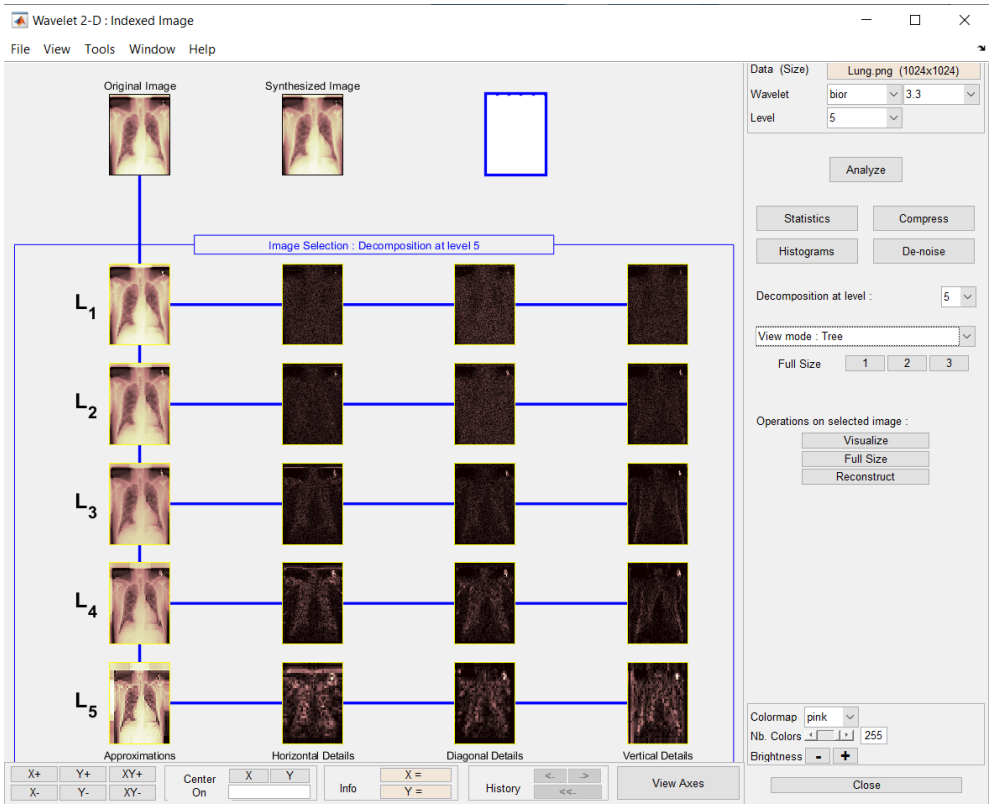
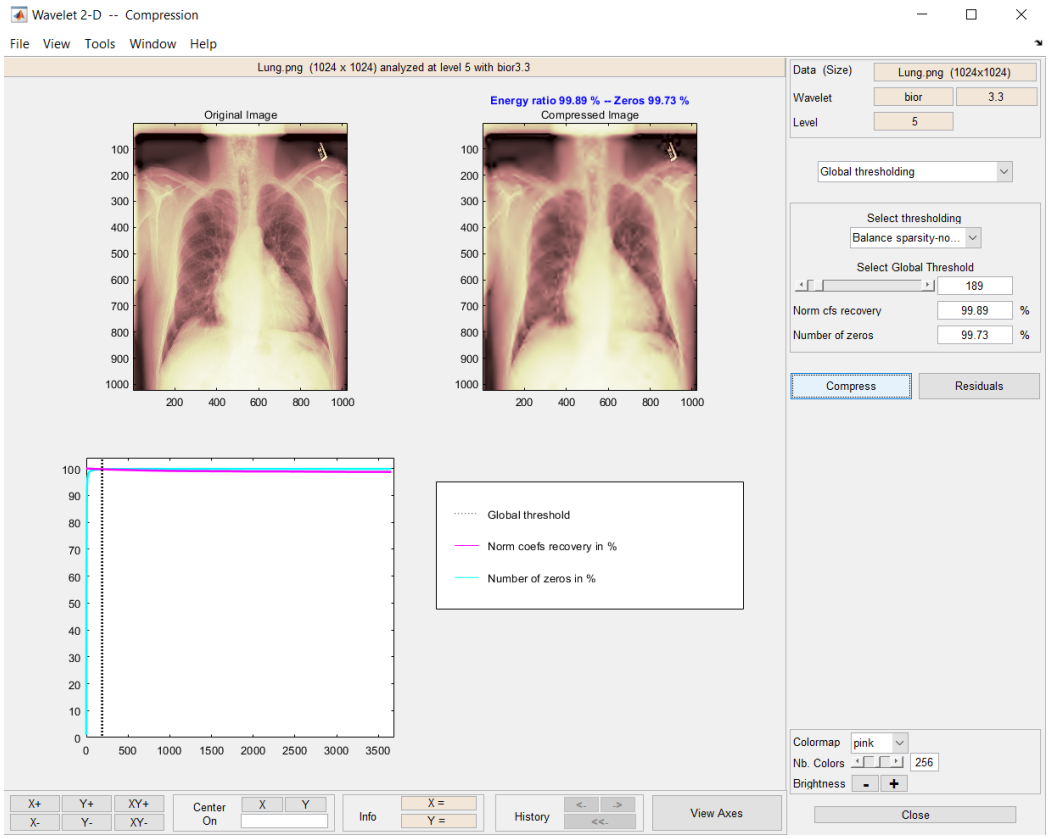
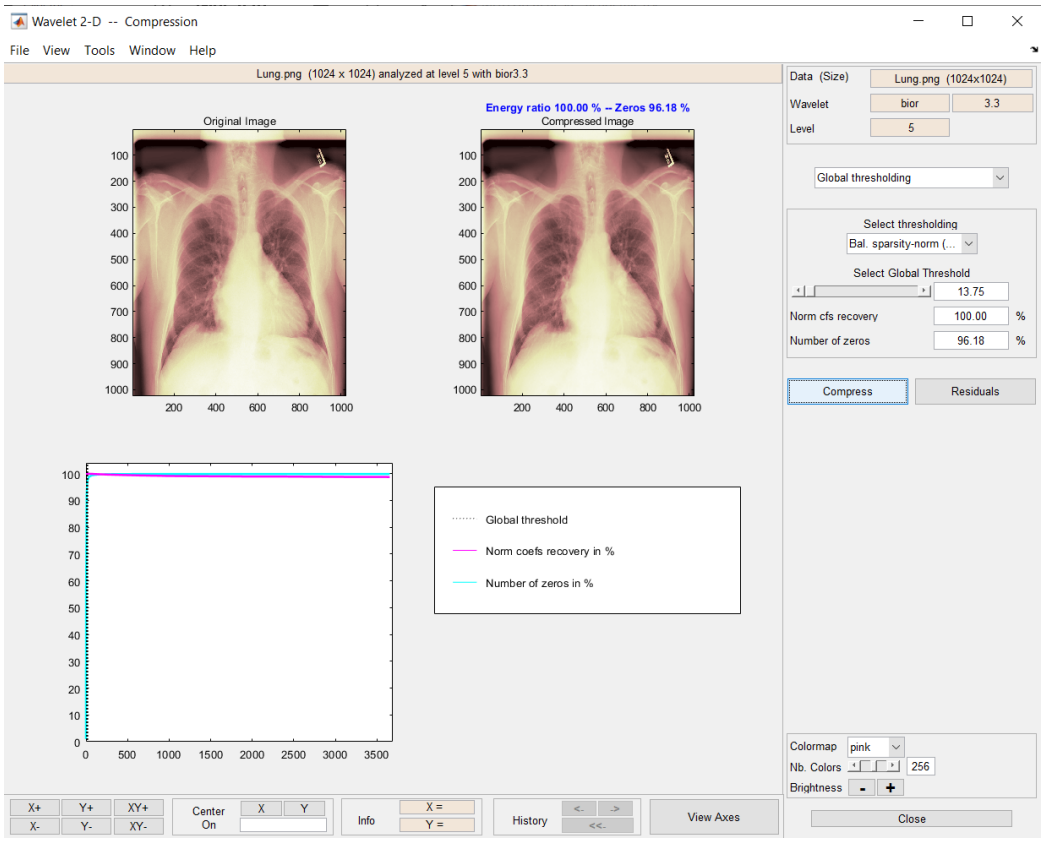


Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



Analysis of the obtained results

Wavelet Type	Equal Balance sparsity-norm			Equal Balance sparsity-norm(sqrt)		
	Threshold	Energy ratio (%)	Number of zeroes (%)	Threshold	Energy ratio (%)	Number of zeroes (%)
Db 1 level 2	278.5	99.91	93.83	16.75	99.96	93.10
Db 3 level 4	849.1	99.79	99.57	29.14	99.96	98.99
Db 6 level 6	313.5	99.87	99.87	17.71	99.99	98.37
Sym 2 level 4	1291	99.76	99.59	35.93	99.95	99.11
Sym 3 level 4	849.1	99.79	99.57	29.14	99.96	98.99
Sym 4 level 6	228.2	99.87	99.87	15.11	99.99	98.22
Bior 1.1 level 2	278.5	99.98	93.83	16.75	99.99	93.10
Bior 2.2 level 3	786.7	99.99	98.36	28.05	100.00	97.96
Bior 3.3 level 5	189	99.89	99.73	13.75	100.00	96.18

The table shows that wavelet type, level, and sparsity norm choice significantly affect compression results.

- Sym 2 level 4 and Db 3 level 4 achieve the highest energy ratios with sparsity-norm, but with more zeroes, indicating lower compression efficiency.

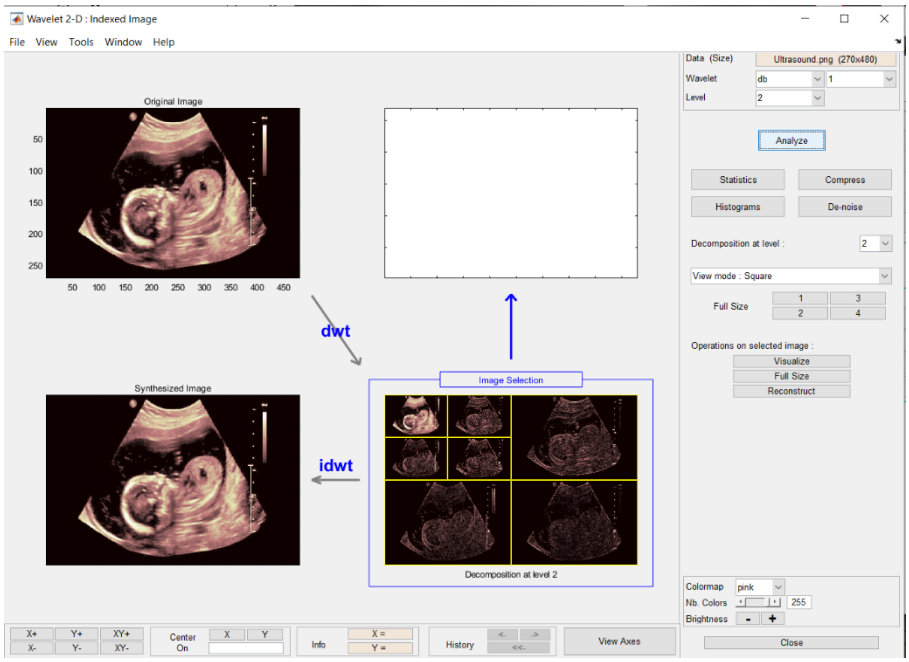
- Using the square root of sparsity-norm, Sym 2 level 4 and Db 3 level 4 maintain high energy ratios with fewer zeroes, balancing compression and quality.

- Bior 2.2 level 3 and Bior 3.3 level 5 excel in both energy retention and compression efficiency with sparsity norm (sqrt), making them ideal for high-fidelity applications.

Overall, the square root of the sparsity norm enhances compression efficiency while preserving image quality across wavelet types and levels.

Using the Wavelet Analyzer toolbox (2-D Wavelet), process the Ultrasound of baby body and spine using the following wavelets

A.db 1 level 2



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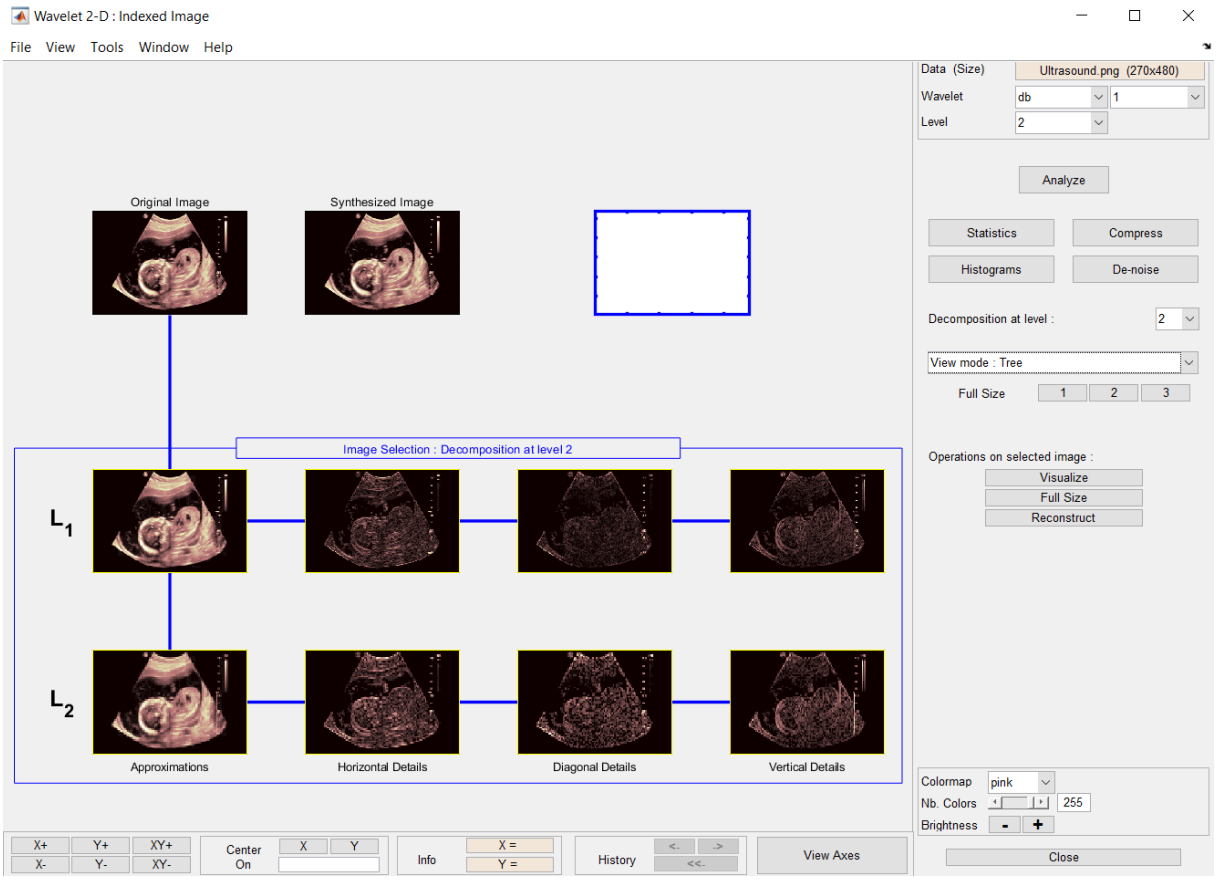
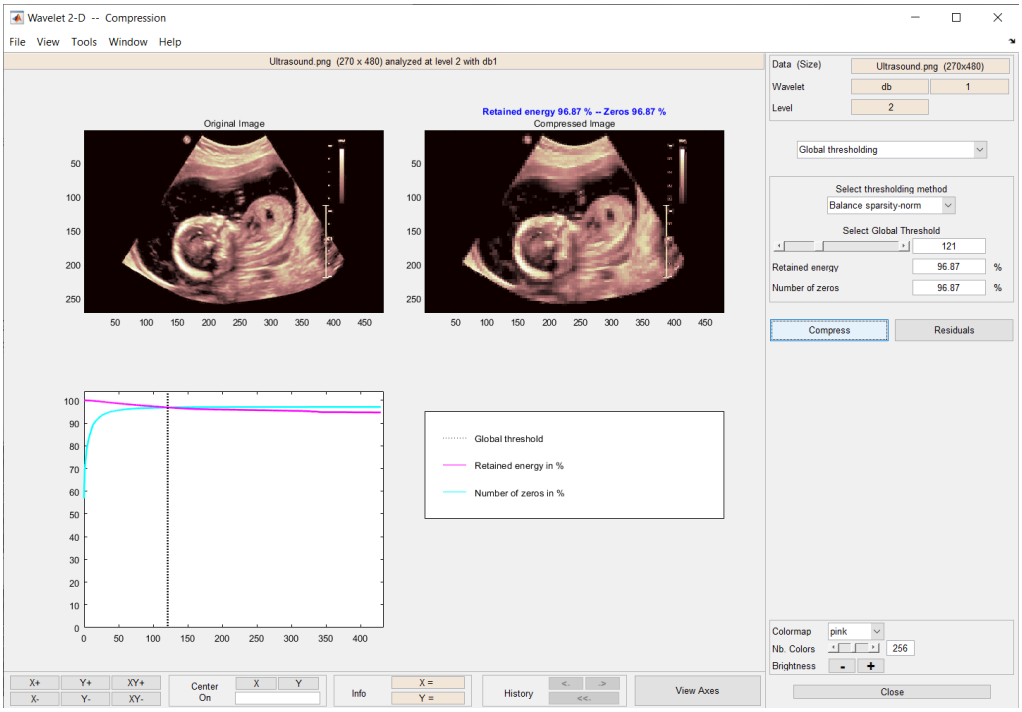
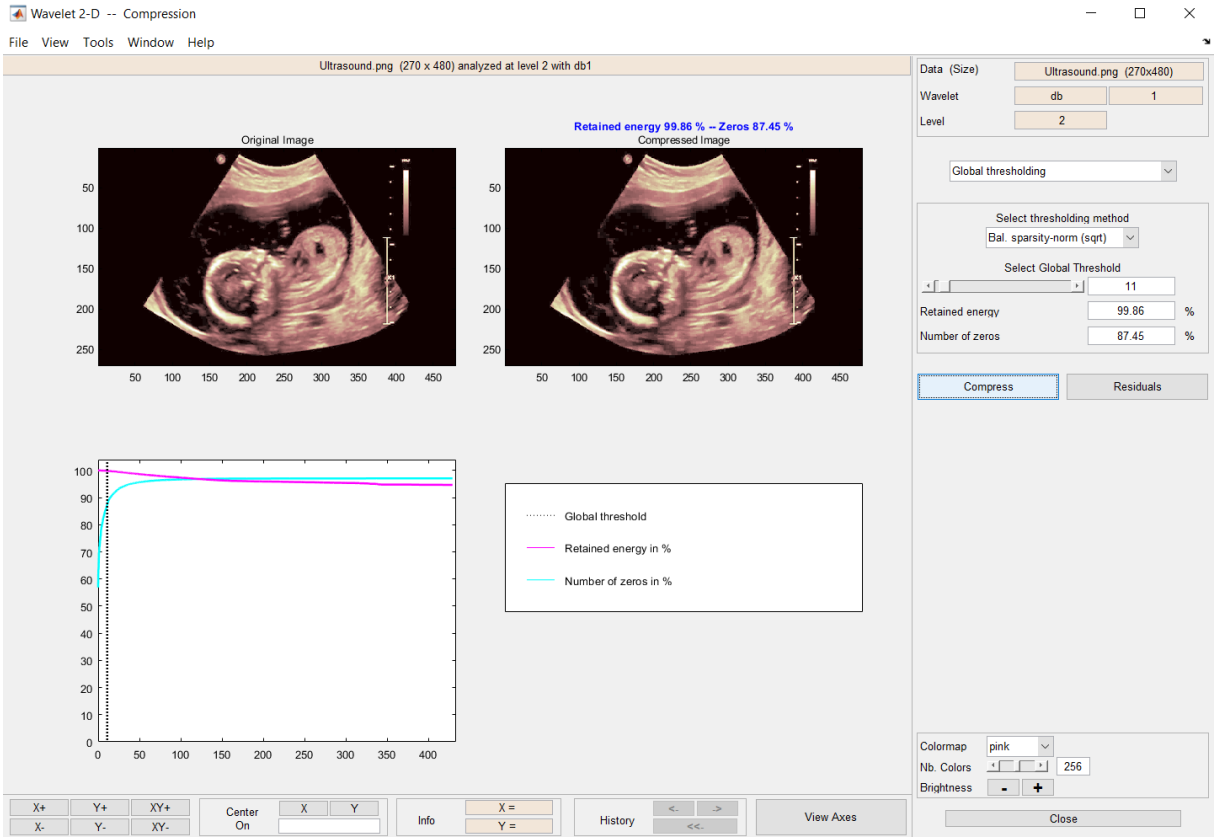


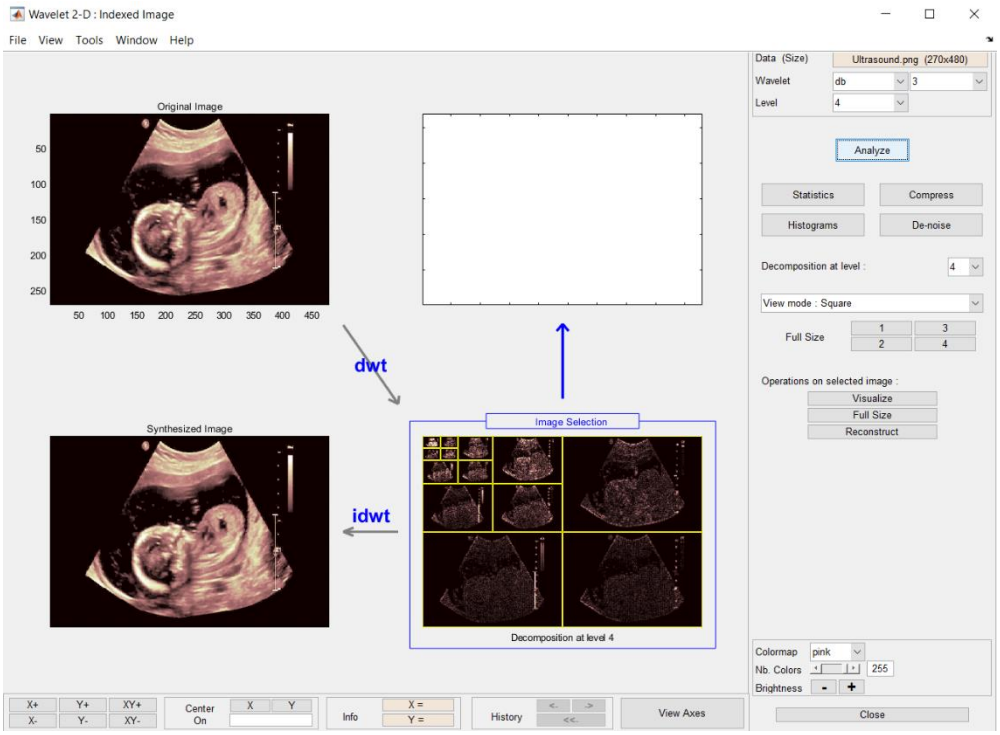
Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



B. db 3 level 4



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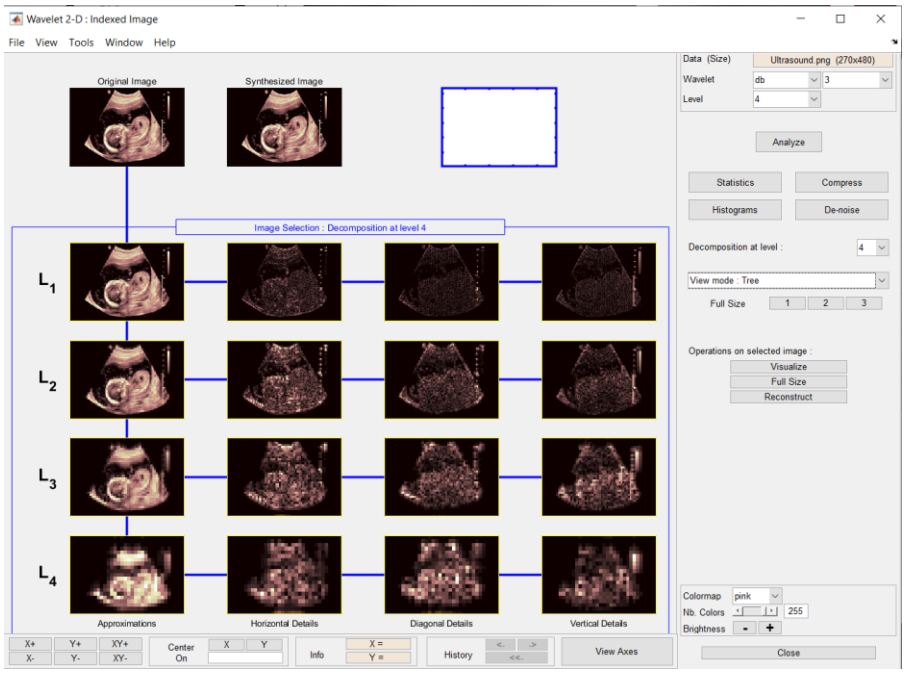
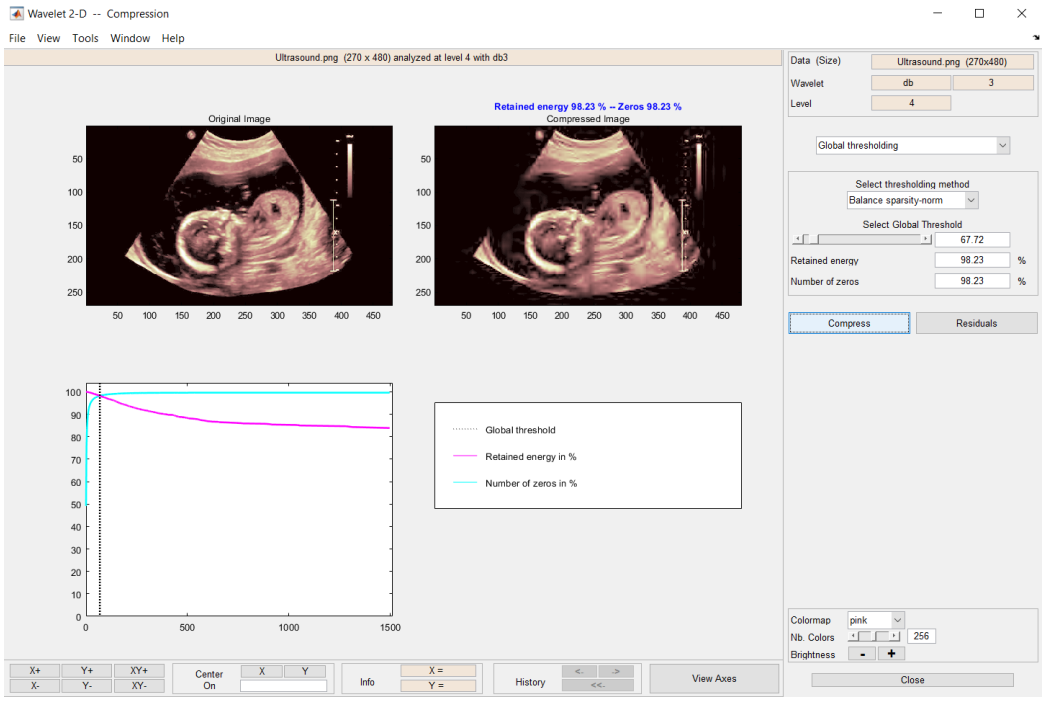
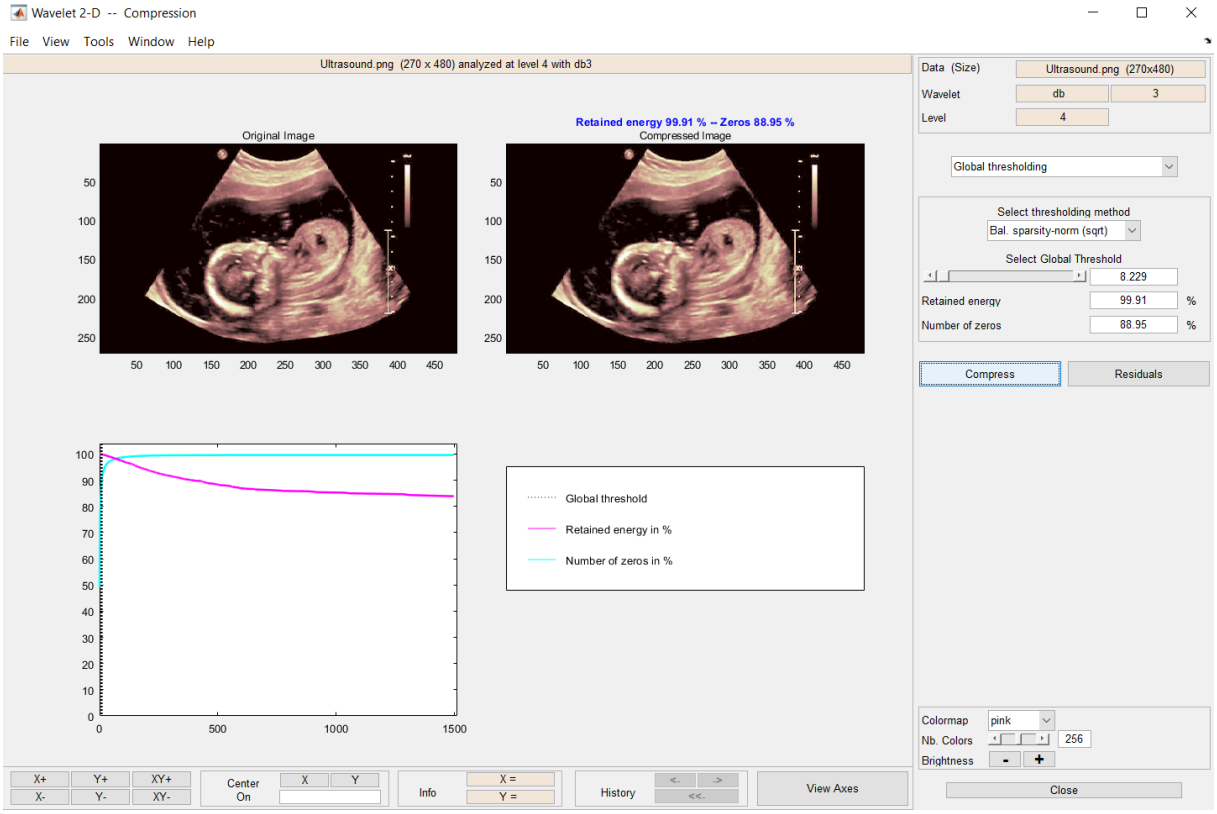


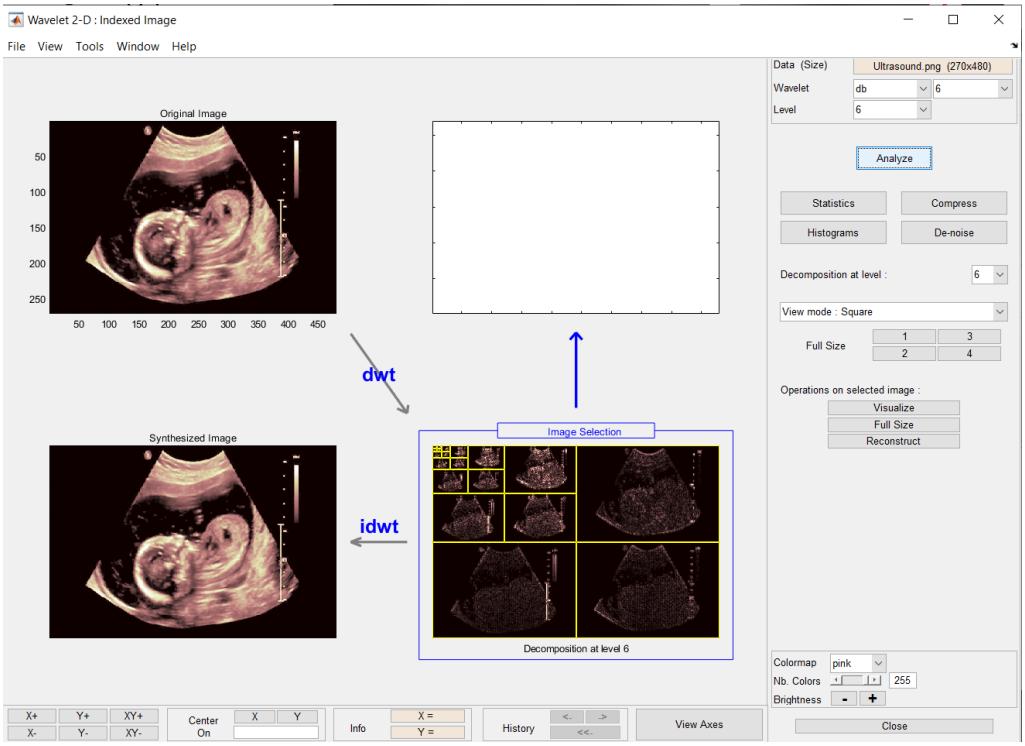
Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



C. db 6 level 6



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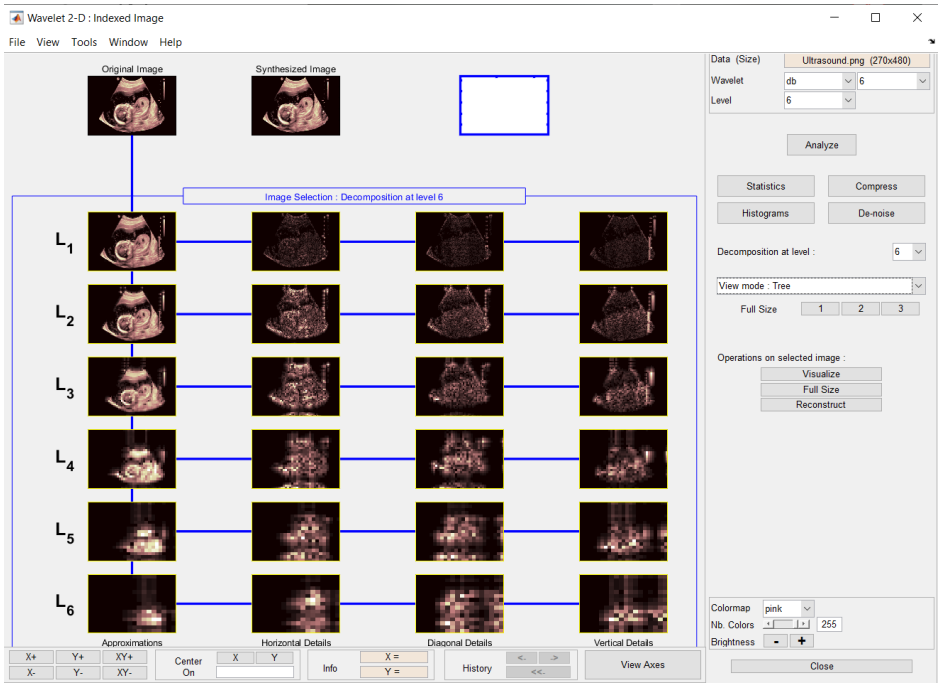
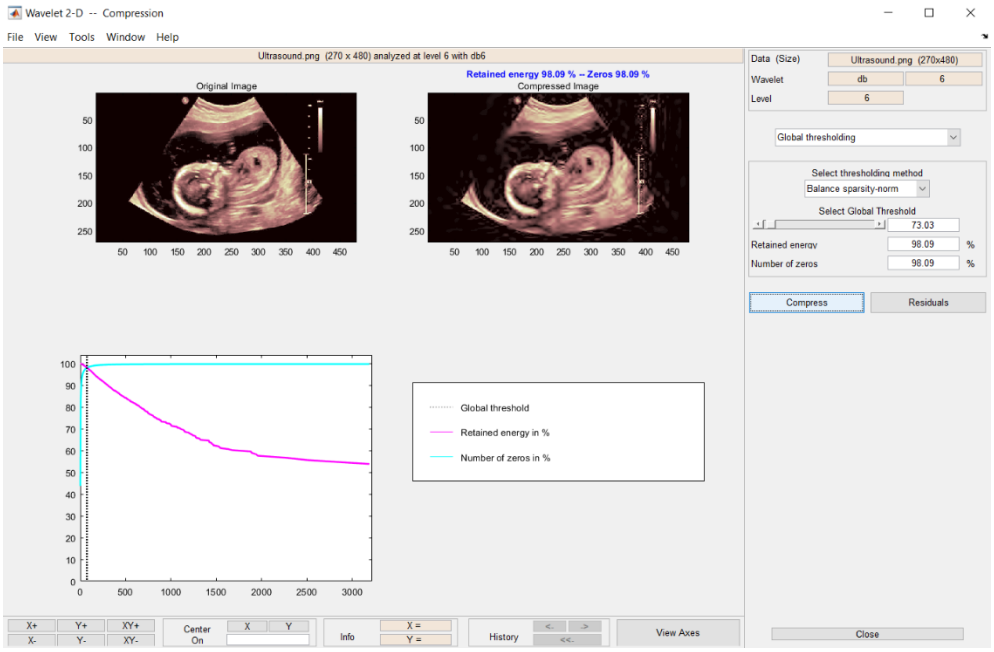
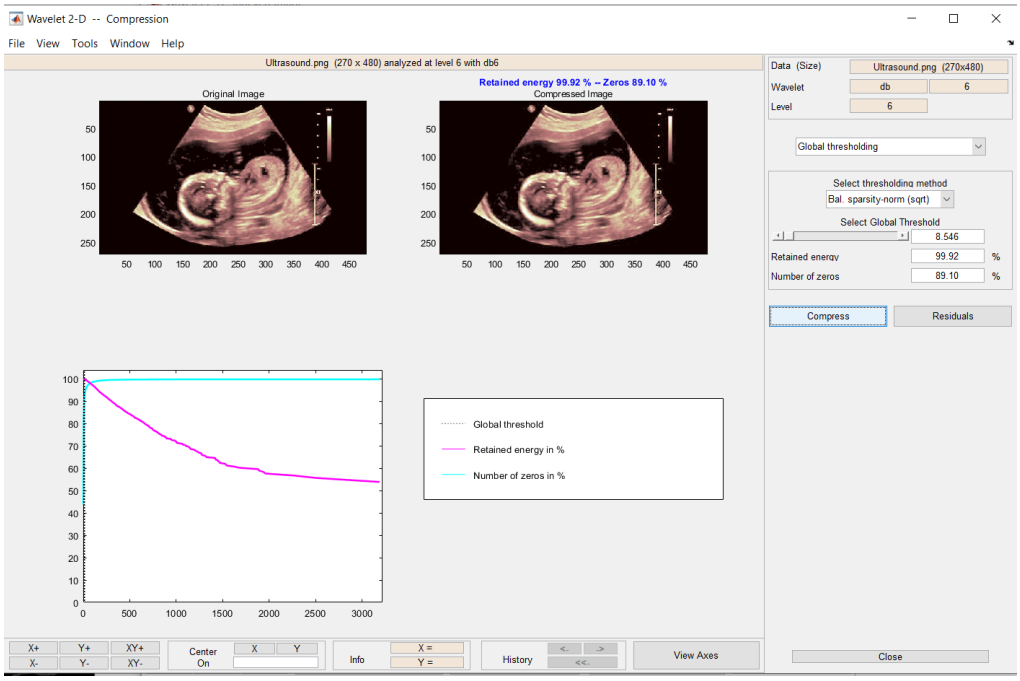


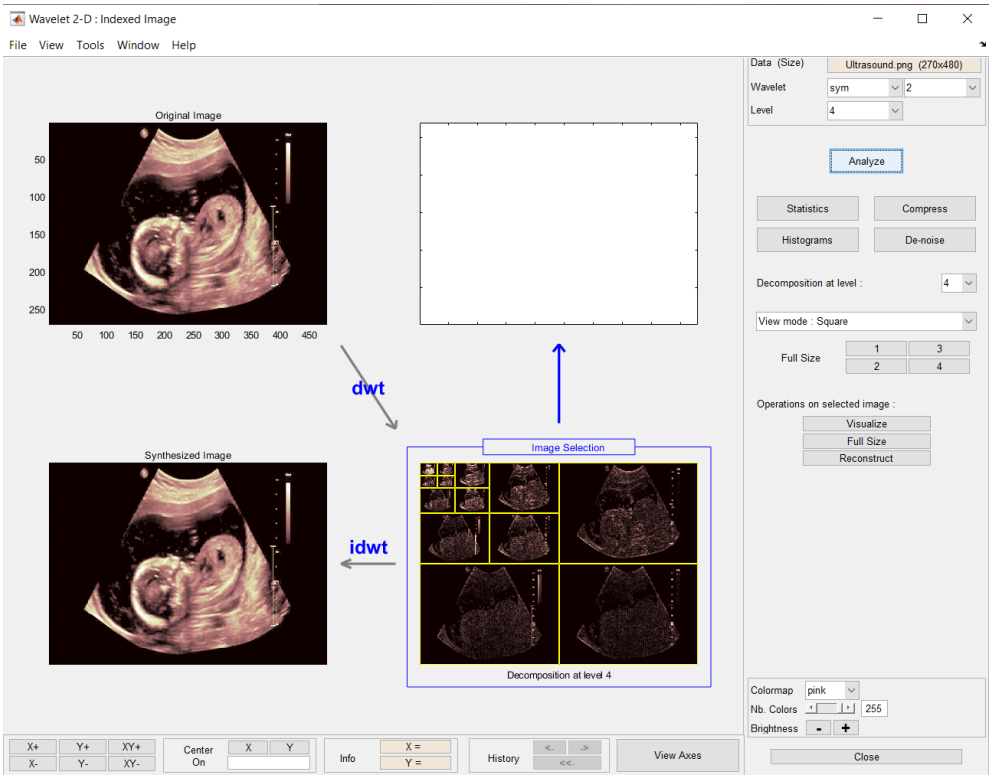
Compress the image using global thresholding with the adopted threshold sparsity-norm



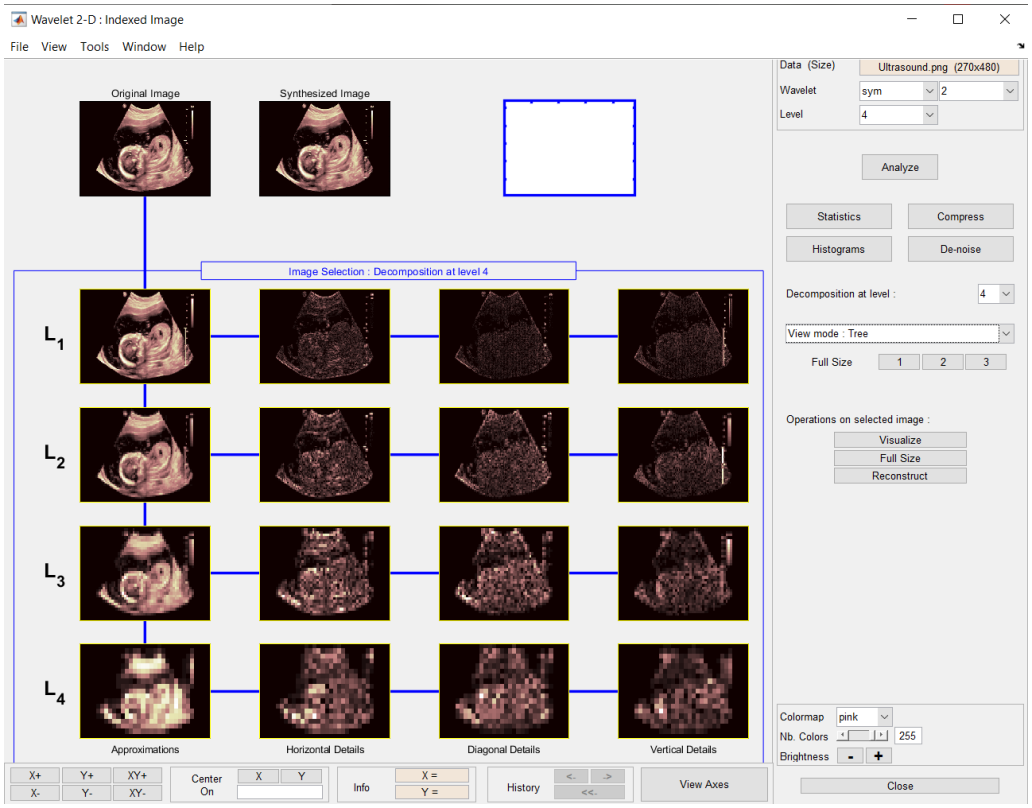
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



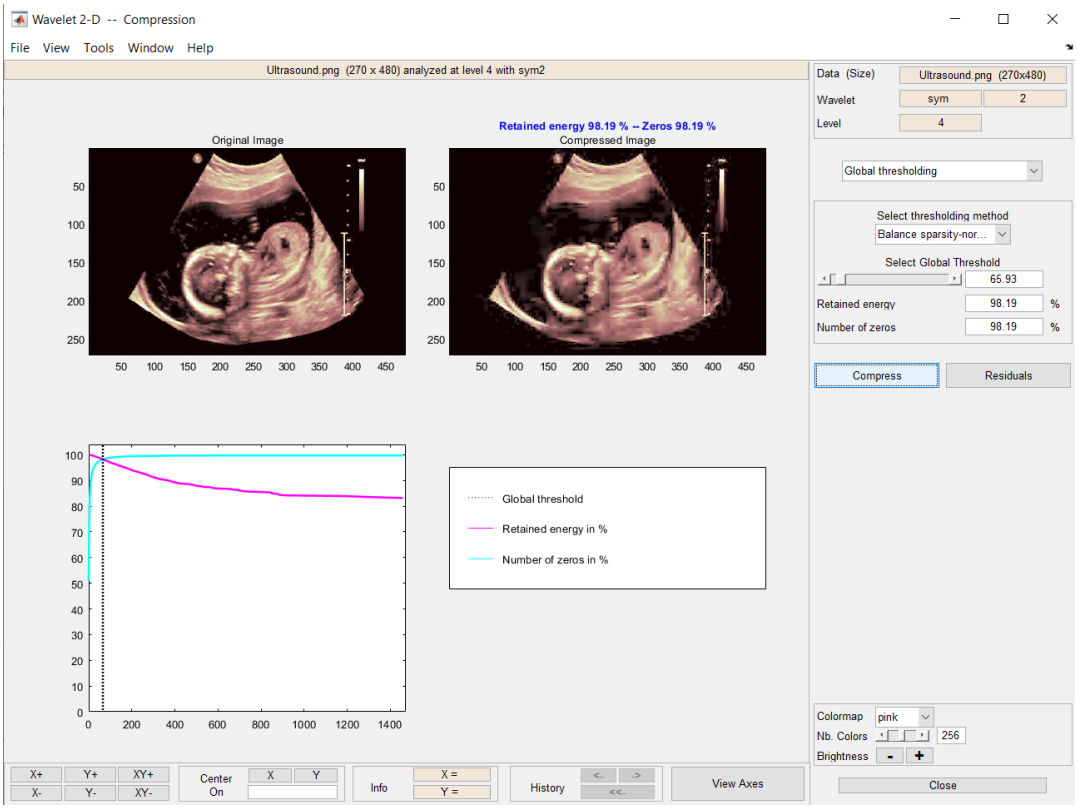
D. sym 2 level 4



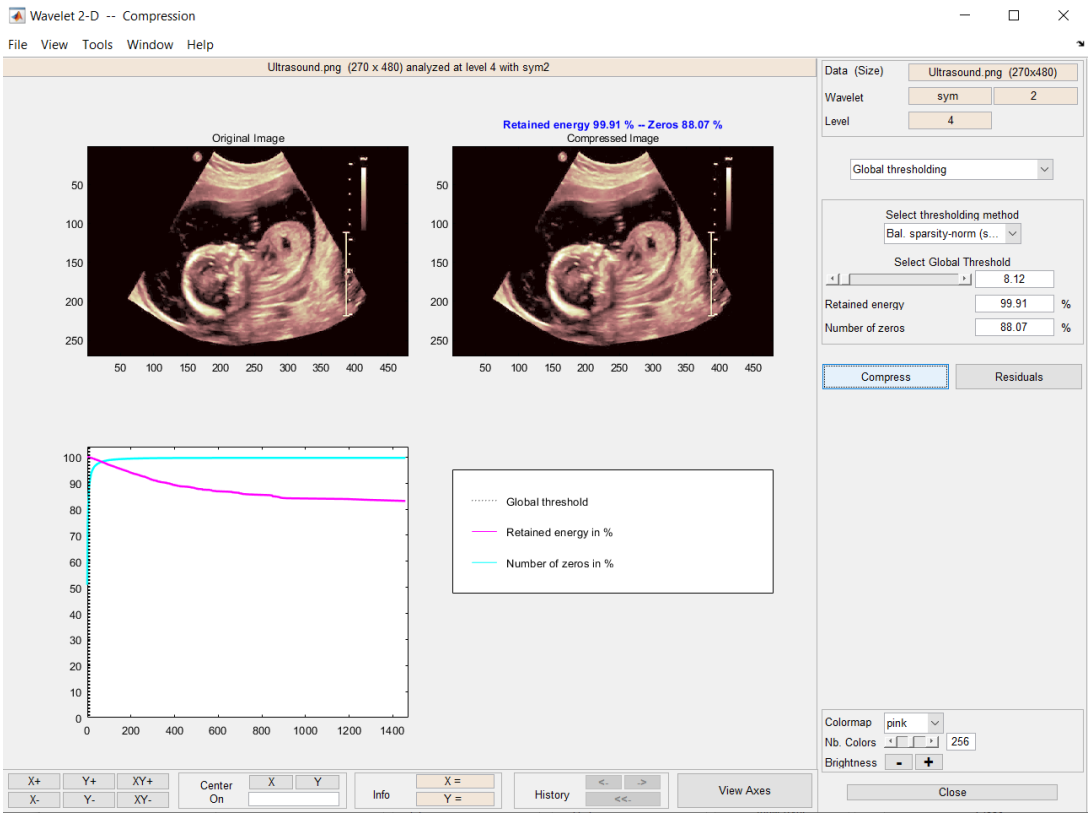
Display the decomposition tree - details and approximations at successive levels of decomposition.



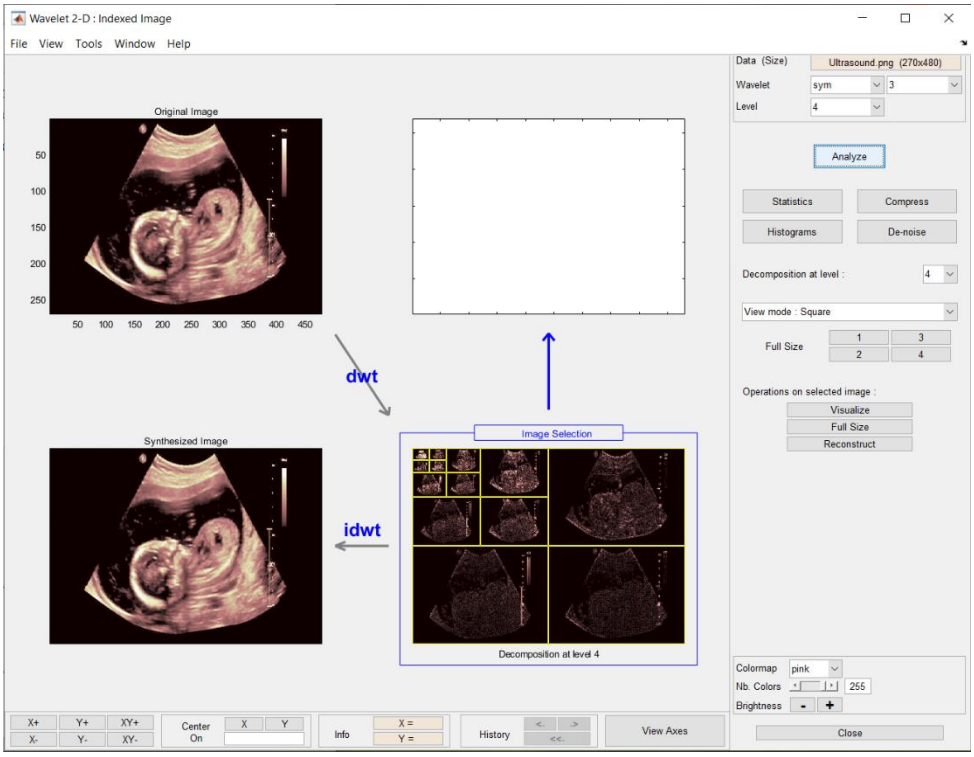
Compress the image using global thresholding with the adopted threshold sparsity-norm



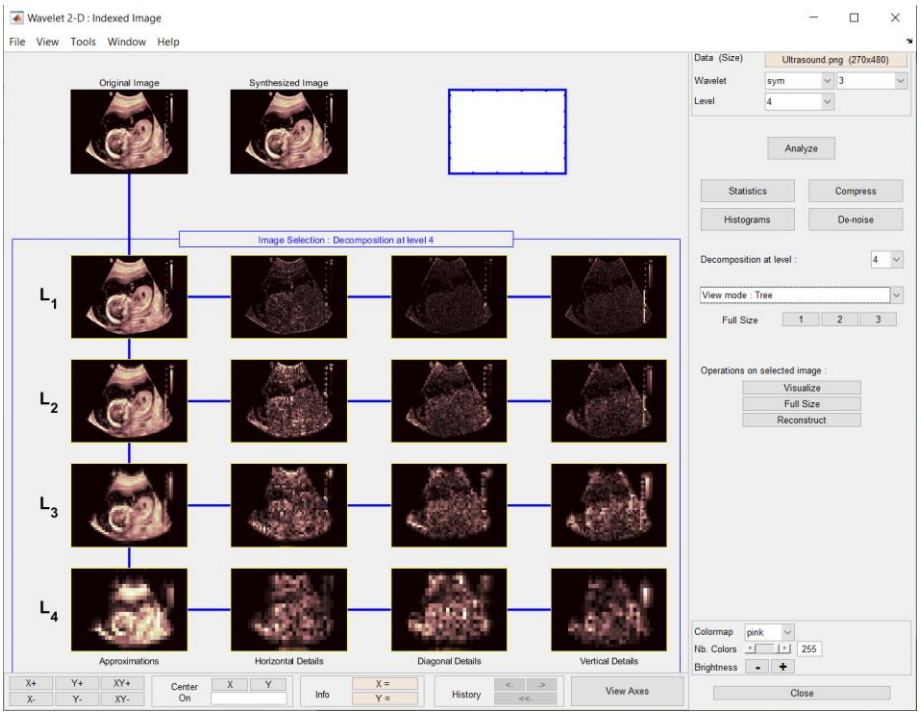
Compress the image using global thresholding with the adopted threshold sparsity-norm(sqrt)



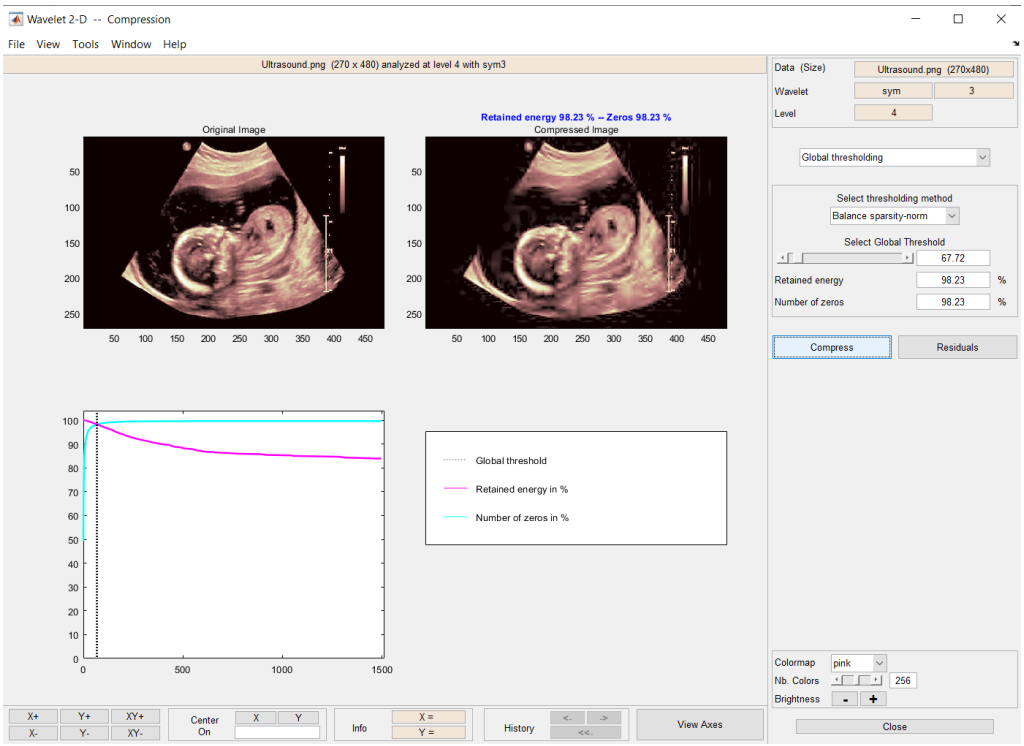
E. sym 3 level 4



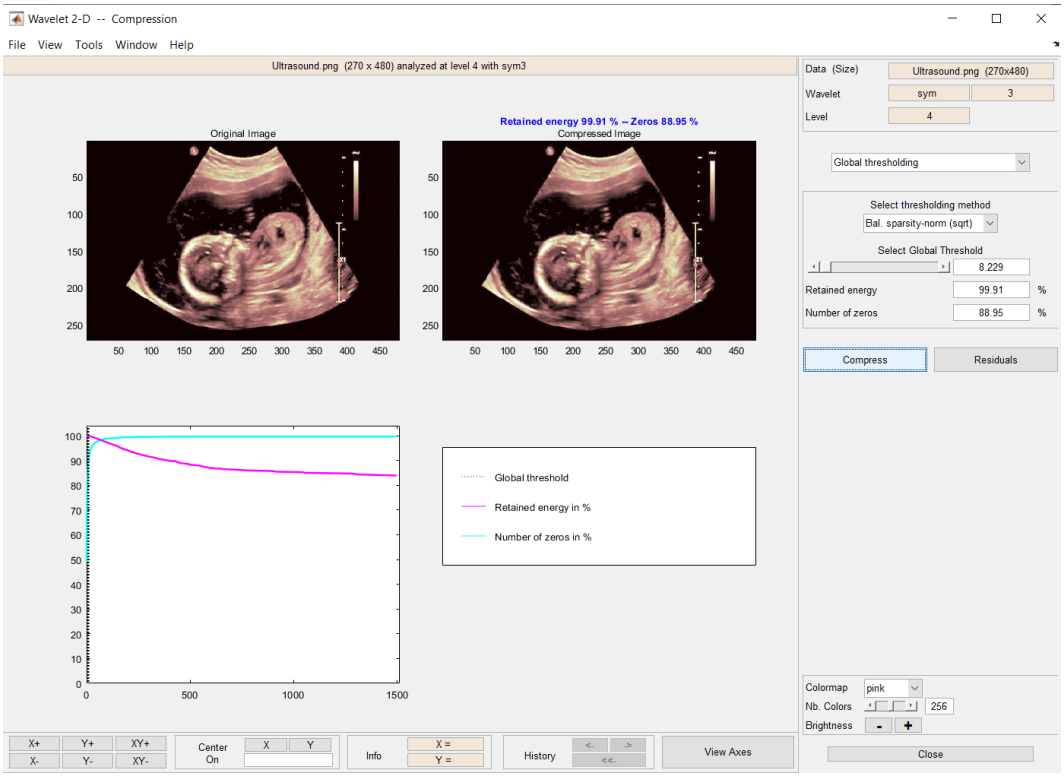
Display the decomposition tree - details and approximations at successive levels of decomposition.



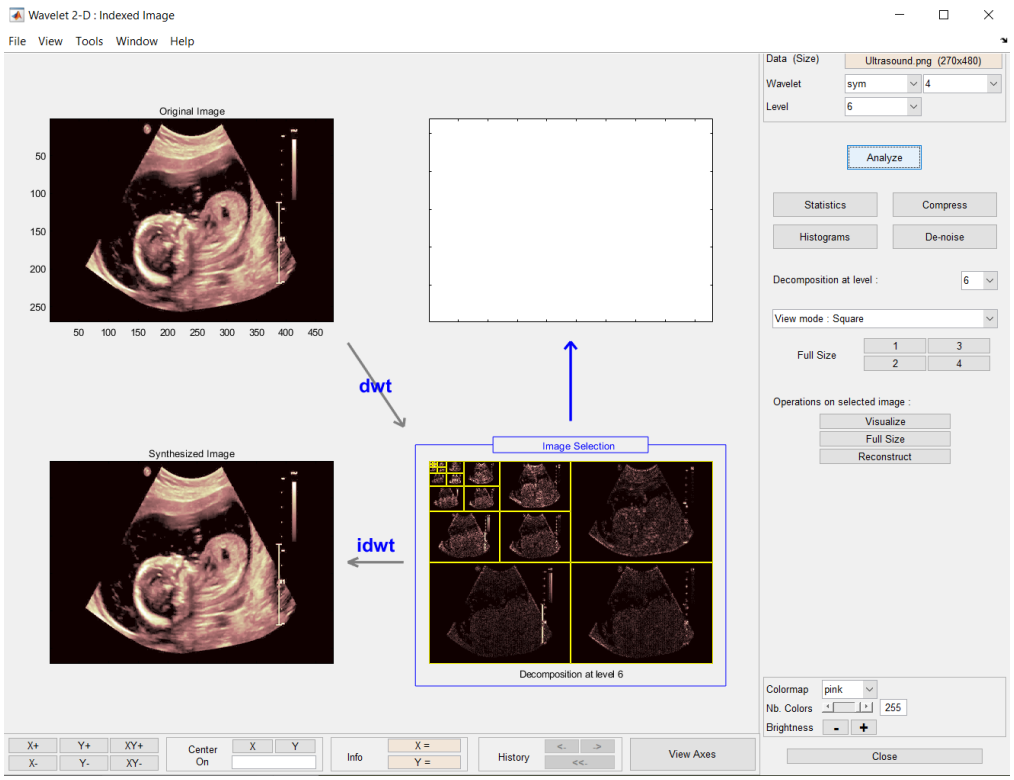
Compress the image using global thresholding with the adopted threshold sparsity-norm



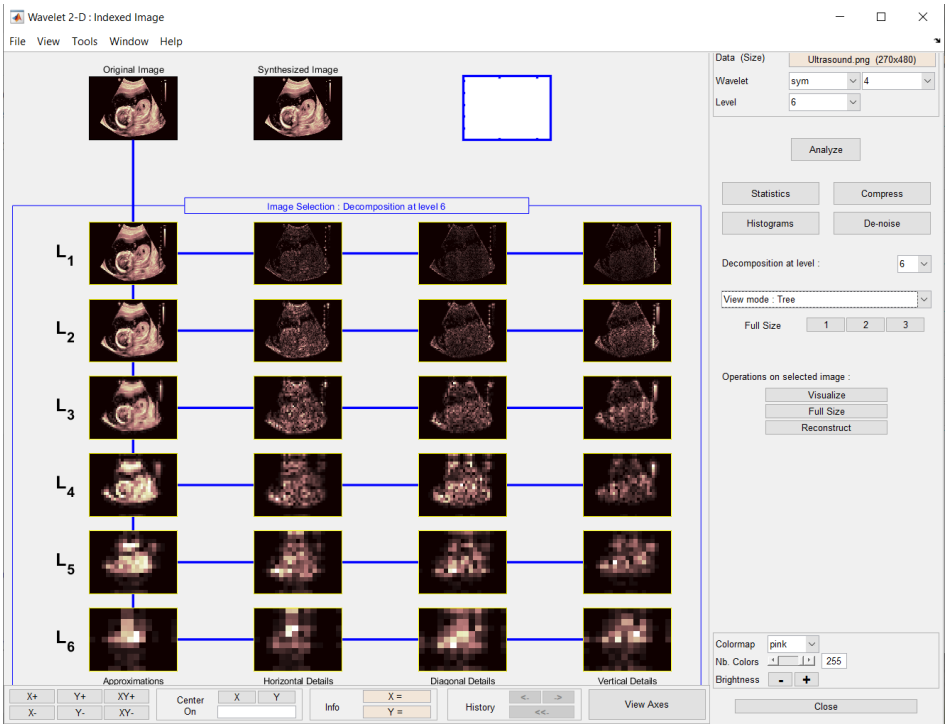
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



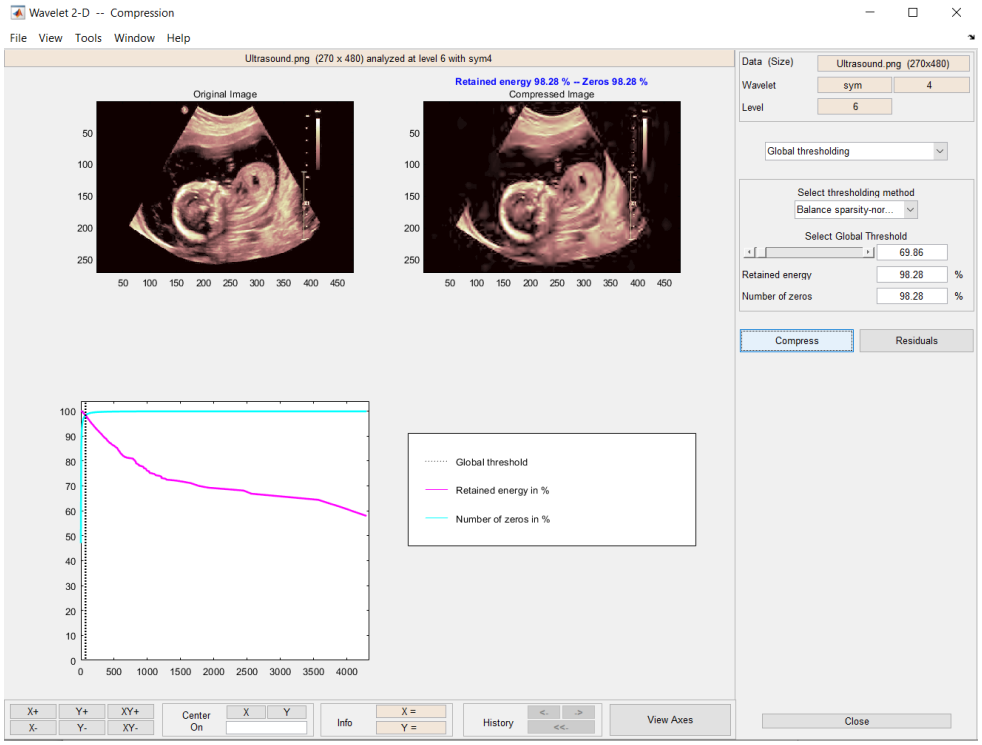
F. sym 4 level 6



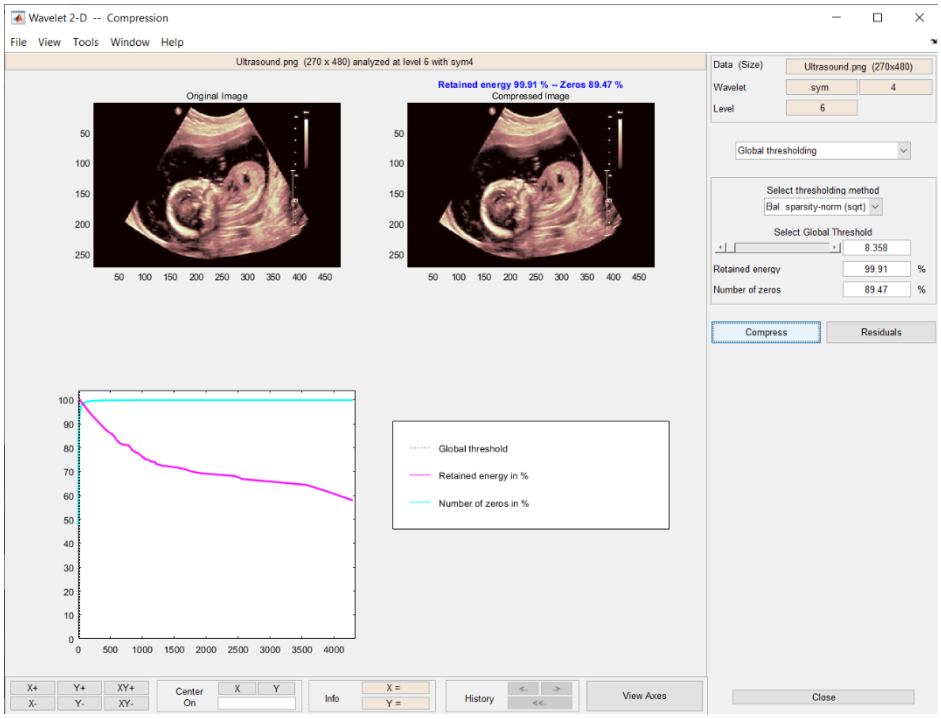
Display the decomposition tree - details and approximations at successive levels of decomposition.



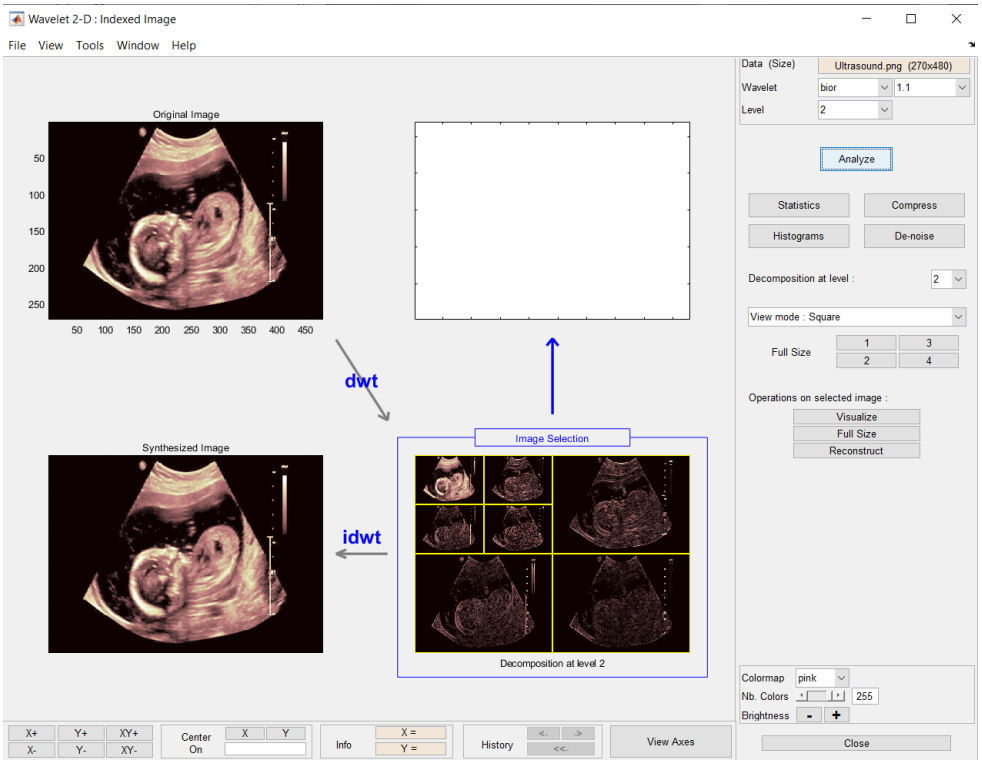
Compress the image using global thresholding with the adopted threshold sparsity-norm



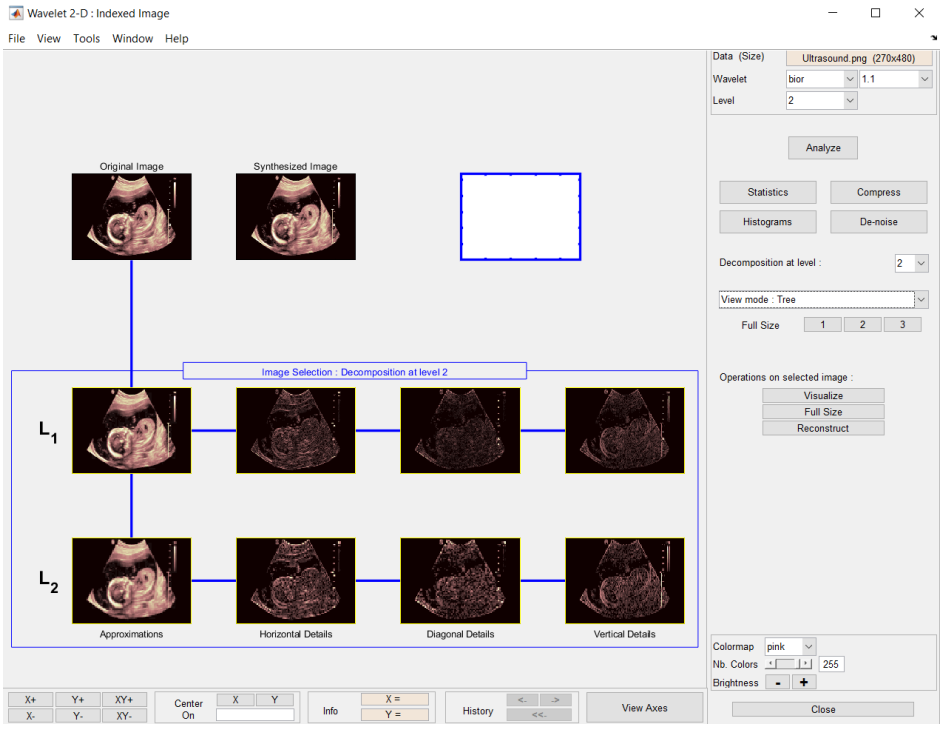
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



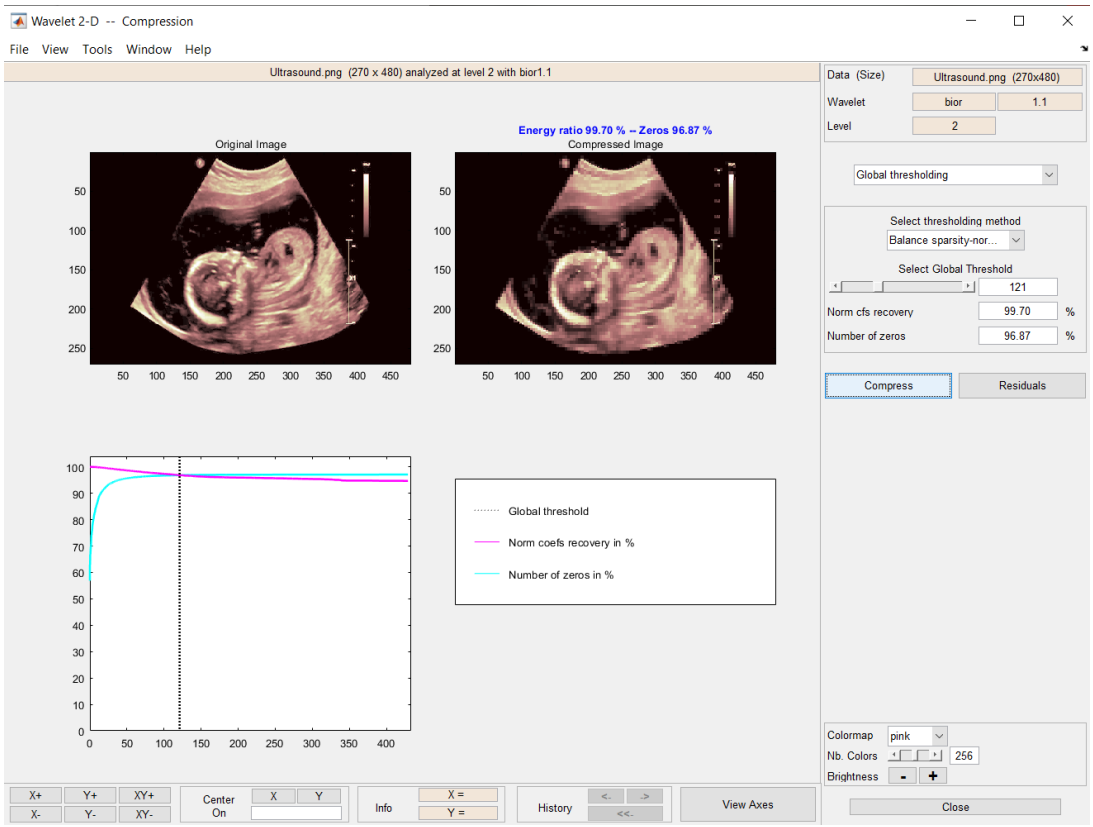
G. bior 1.1: level 2



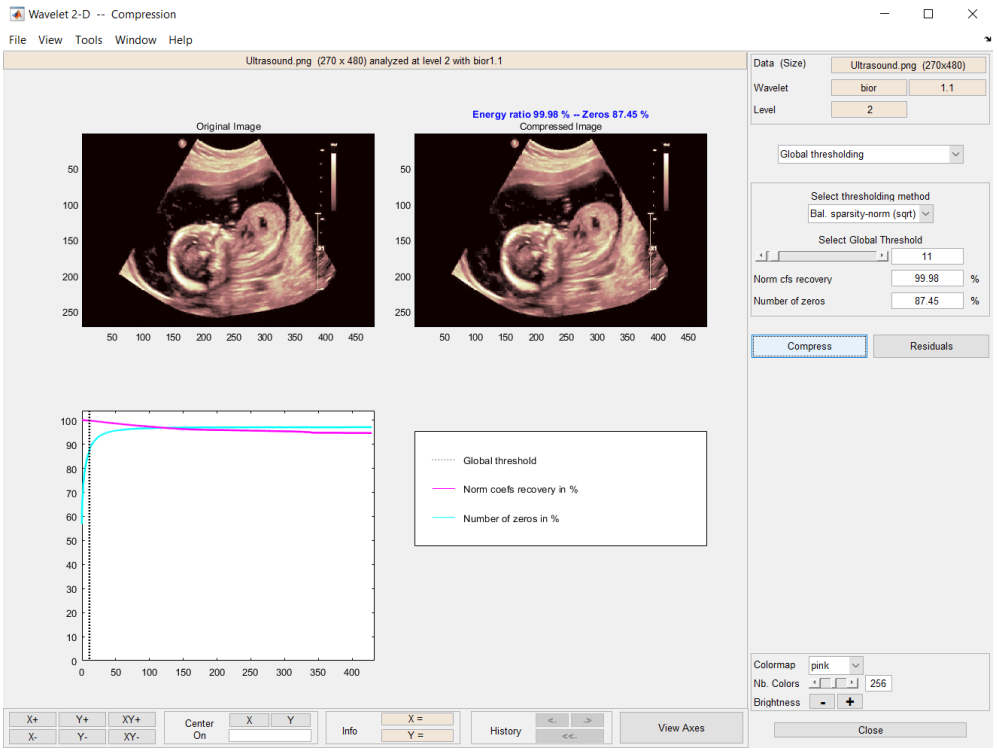
Display the decomposition tree - details and approximations at successive levels of decomposition.



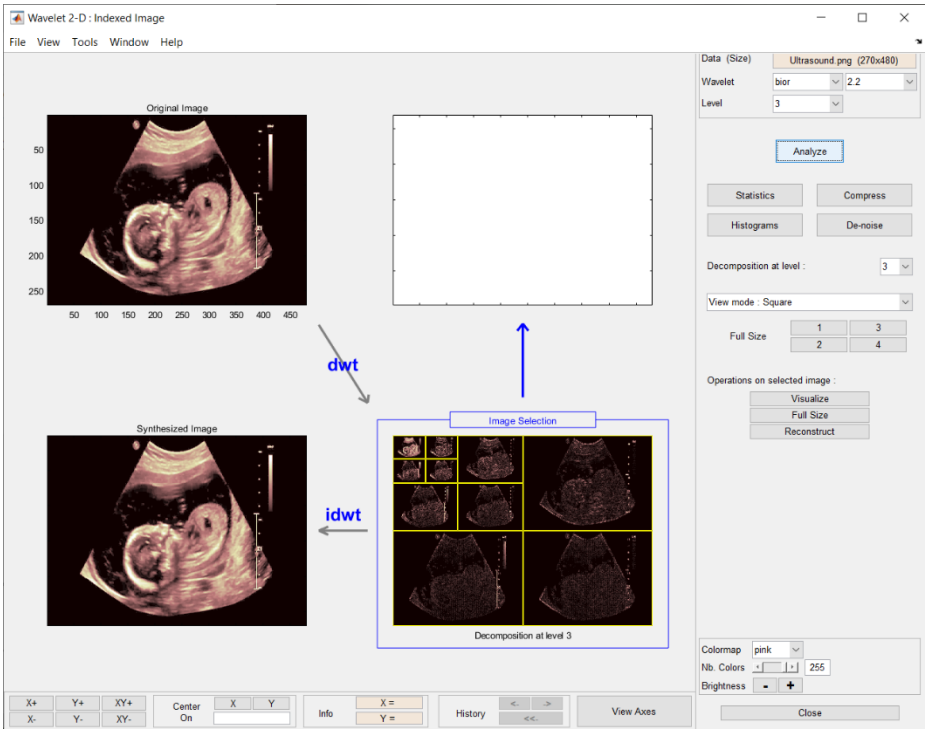
Compress the image using global thresholding with the adopted threshold sparsity-norm



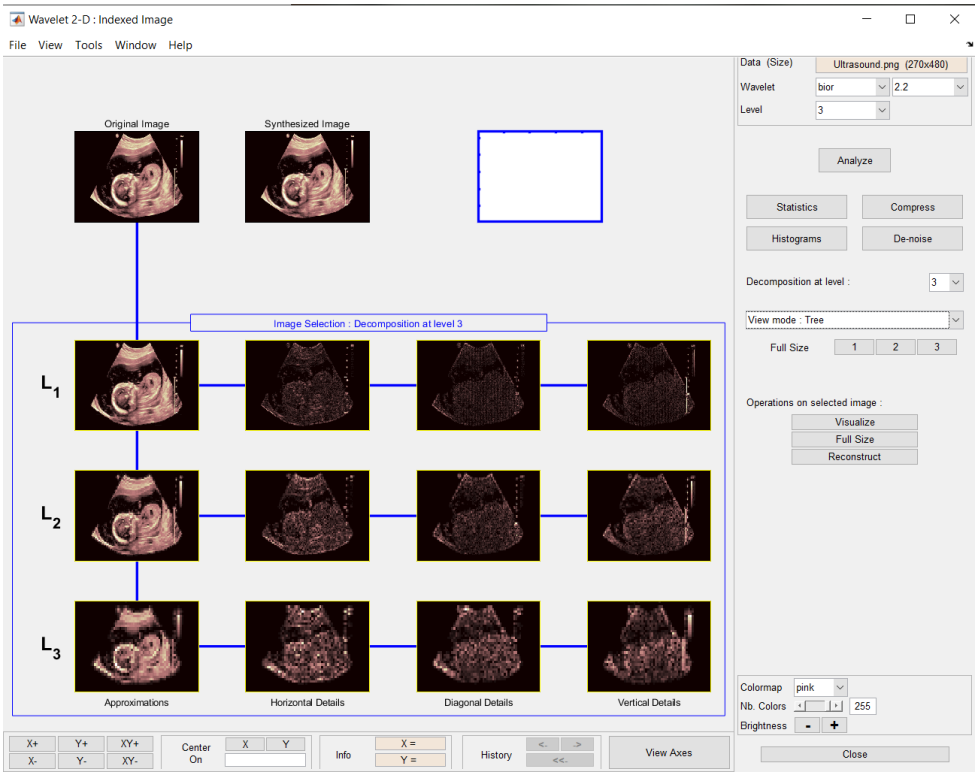
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



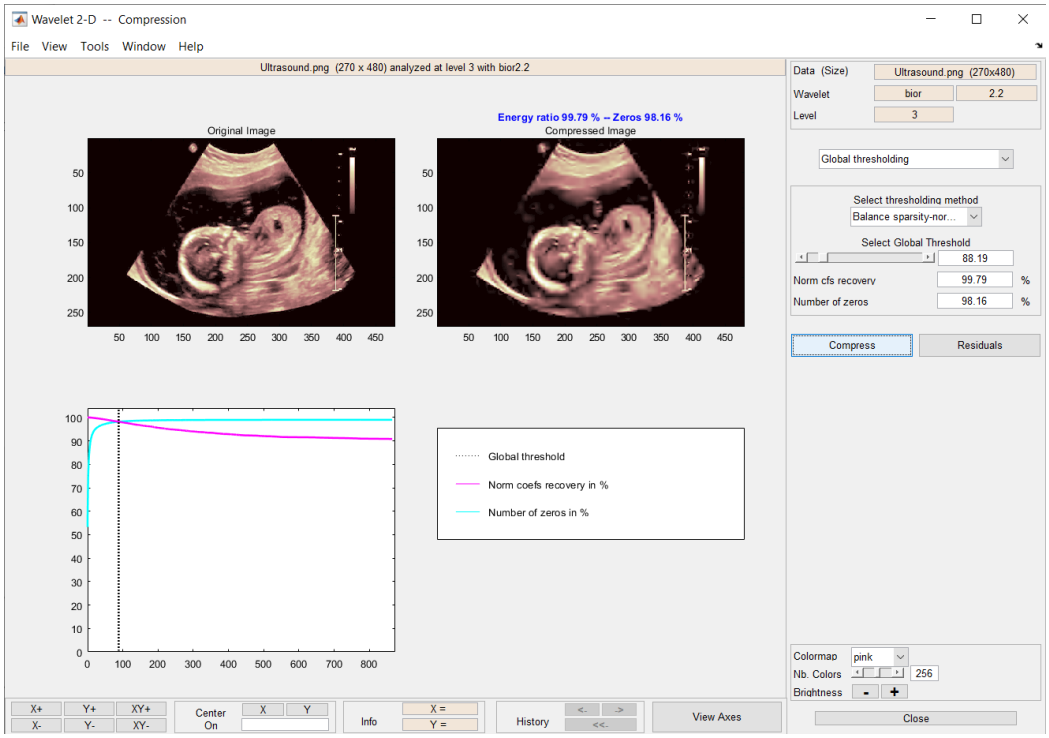
H. bior 2.2: level 3



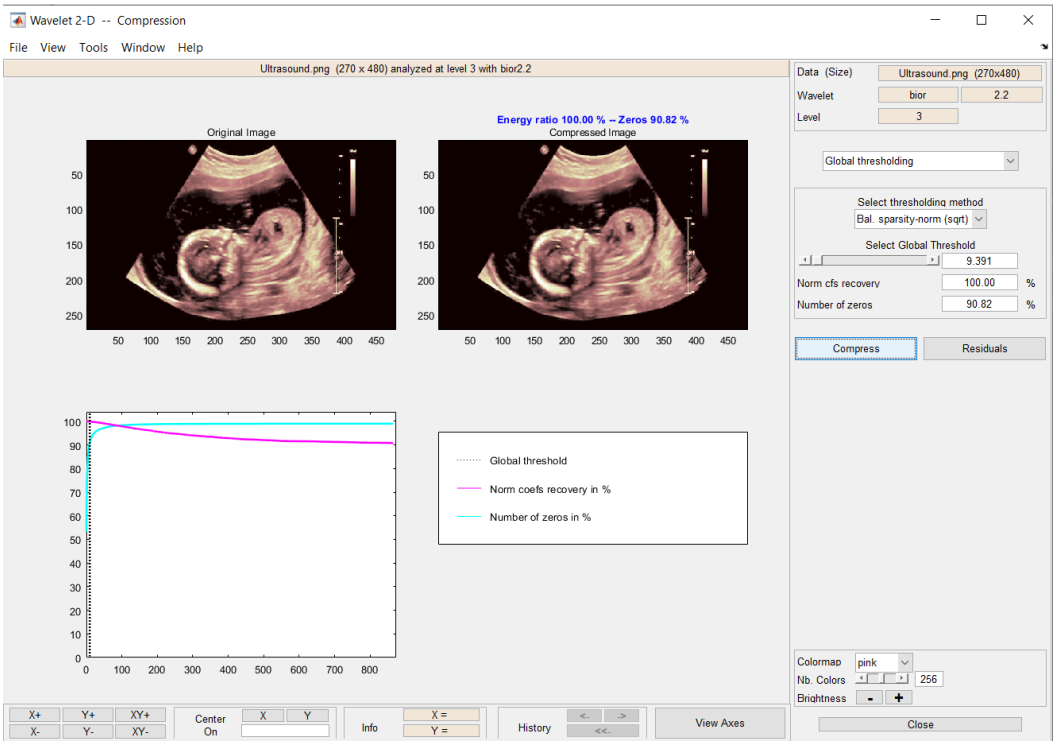
Display the decomposition tree - details and approximations at successive levels of decomposition.



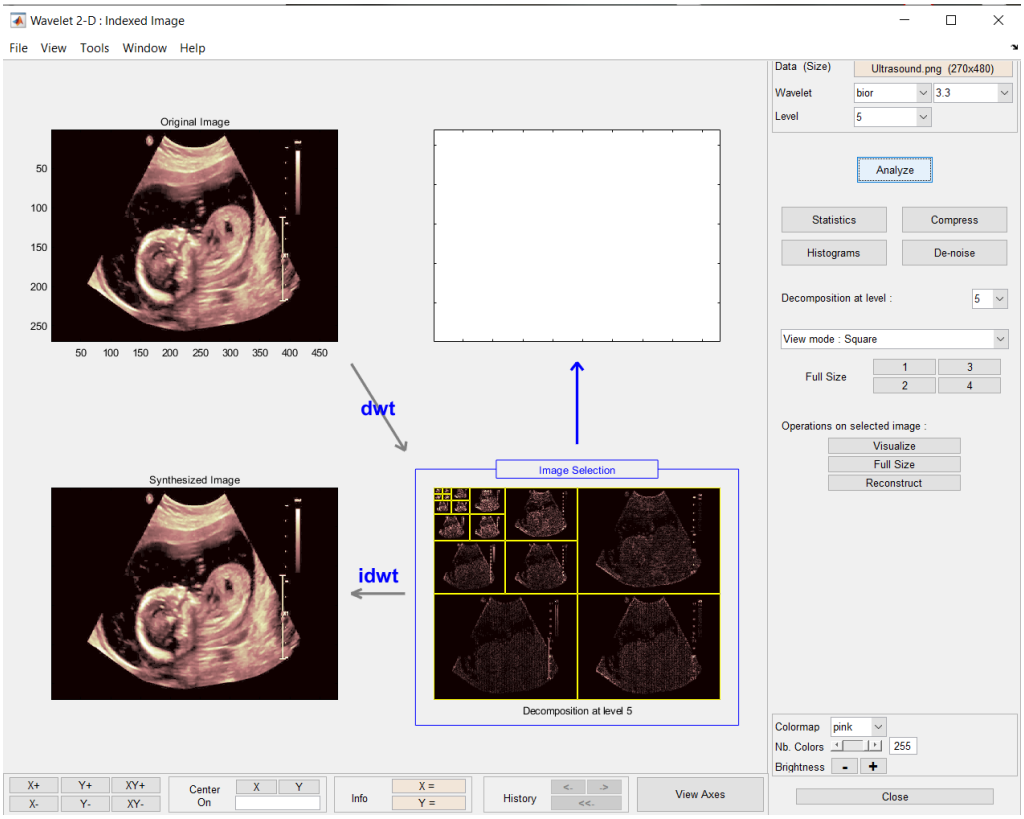
Compress the image using global thresholding with the adopted threshold sparsity-norm



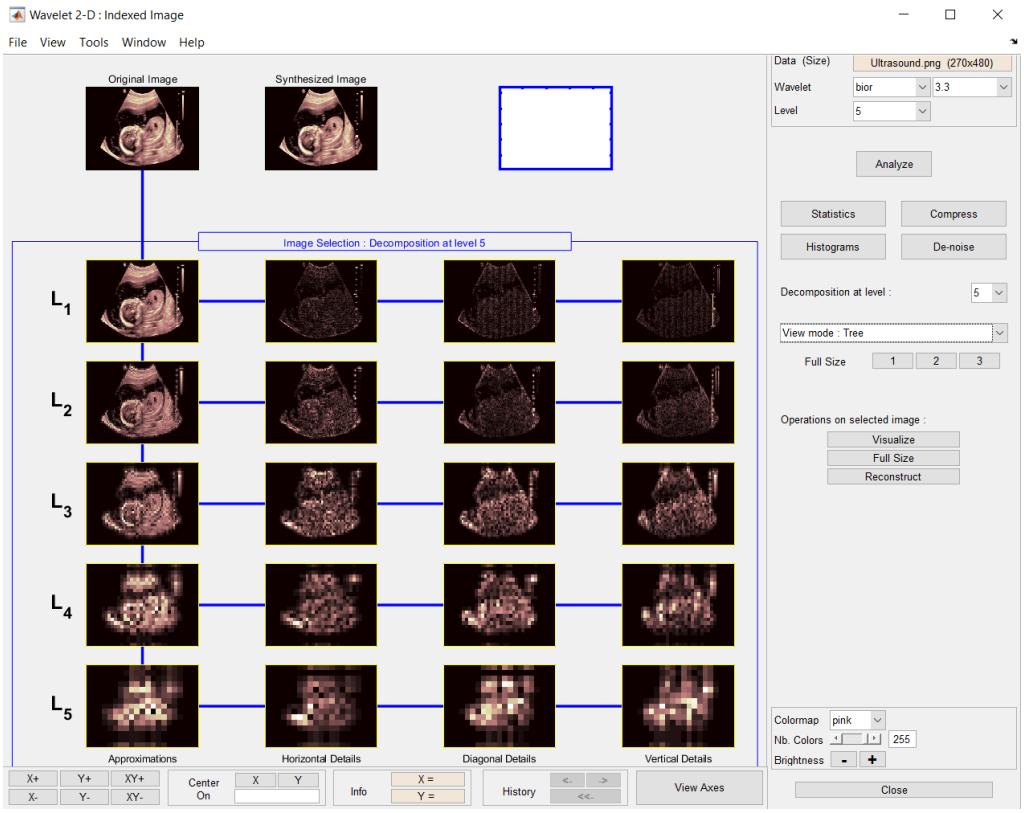
Compress the image using global thresholding with the adopted threshold parsity norm (sqrt)



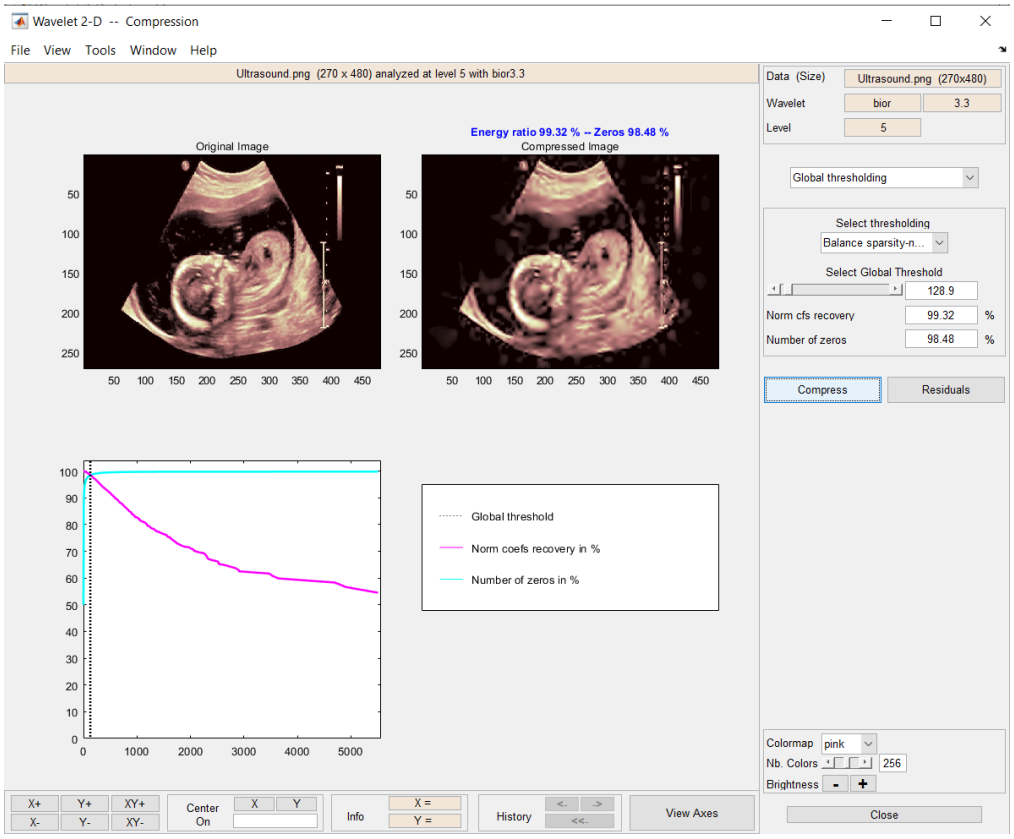
I bior 3.3: level 5



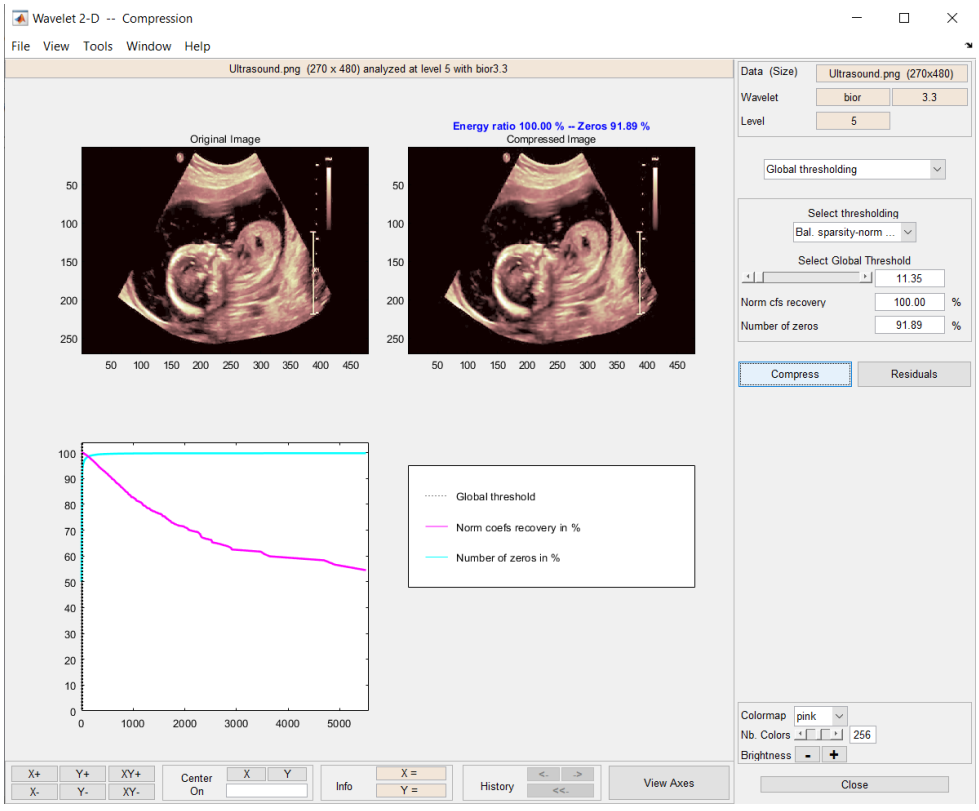
Display the decomposition tree - details and approximations at successive levels of decomposition.



Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



Analysis of the obtained results

Wavelet Type	Equal Balance sparsity-norm			Equal Balance sparsity-norm(sqrt)		
	Threshold	Energy ratio (%)	Number of zeroes (%)	Threshold	Energy ratio (%)	Number of zeroes (%)
Db 1 level 2	121	96.87	96.87	11	99.86	87.45
Db 3 level 4	67.72	98.23	98.23	8.229	99.91	88.95
Db 6 level 6	73.03	98.09	98.09	8.546	99.92	89.10
Sym 2 level 4	65.93	98.19	98.19	8.12	99.91	88.07
Sym 3 level 4	67.62	98.23	98.23	8.229	99.91	88.95
Sym 4 level 6	69.86	98.28	98.28	8.358	99.91	89.47
Bior 1.1 level 2	121	99.70	96.87	11	99.98	87.45
Bior 2.2 level 3	88.19	99.79	98.16	9.391	100.00	90.82
Bior 3.3 level 5	128.9	99.32	98.48	11.35	100.00	91.89

The analysis reveals that wavelet types and their levels significantly affect energy ratio and number of zeroes during image compression.

- Db 1 level 2 and Bior 1.1 level 2exhibit the highest energy ratios with sparsity-norm, indicating strong detail retention but with a high number of zeroes, suggesting less efficient compression.

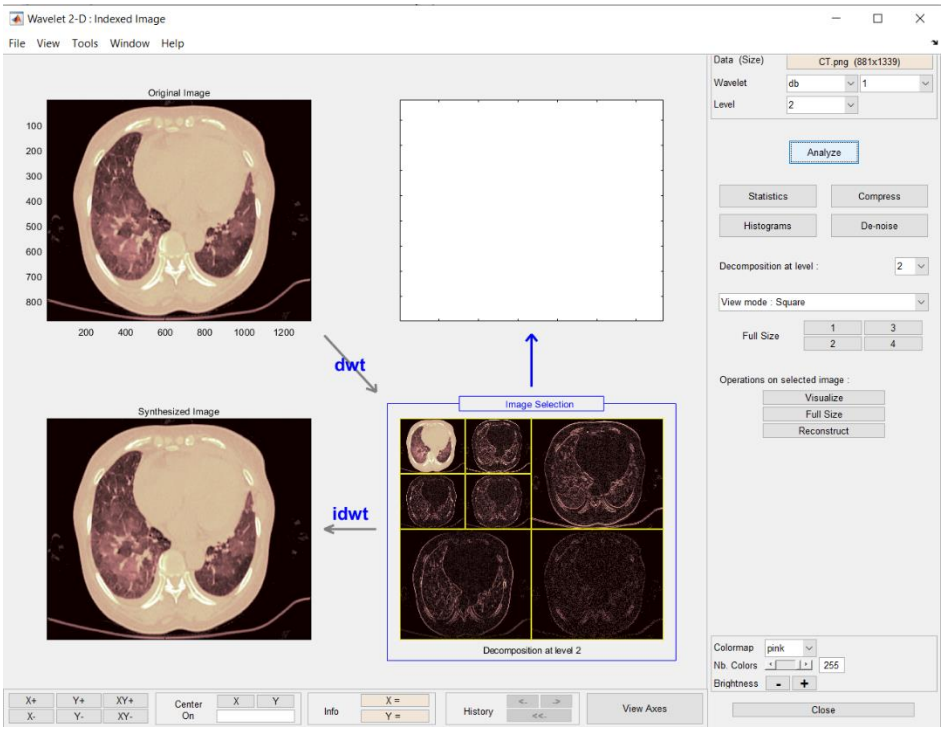
- Bior 2.2 level 3 and Bior 3.3 level 5 provide the highest energy retention and zero compression when using sparsity norm (sqrt), making them ideal for applications requiring high fidelity.

- Db 6 level 6 and Sym 4 level 6 show a balanced performance, maintaining good energy ratios and a moderate number of zeroes, suitable for general purposes.

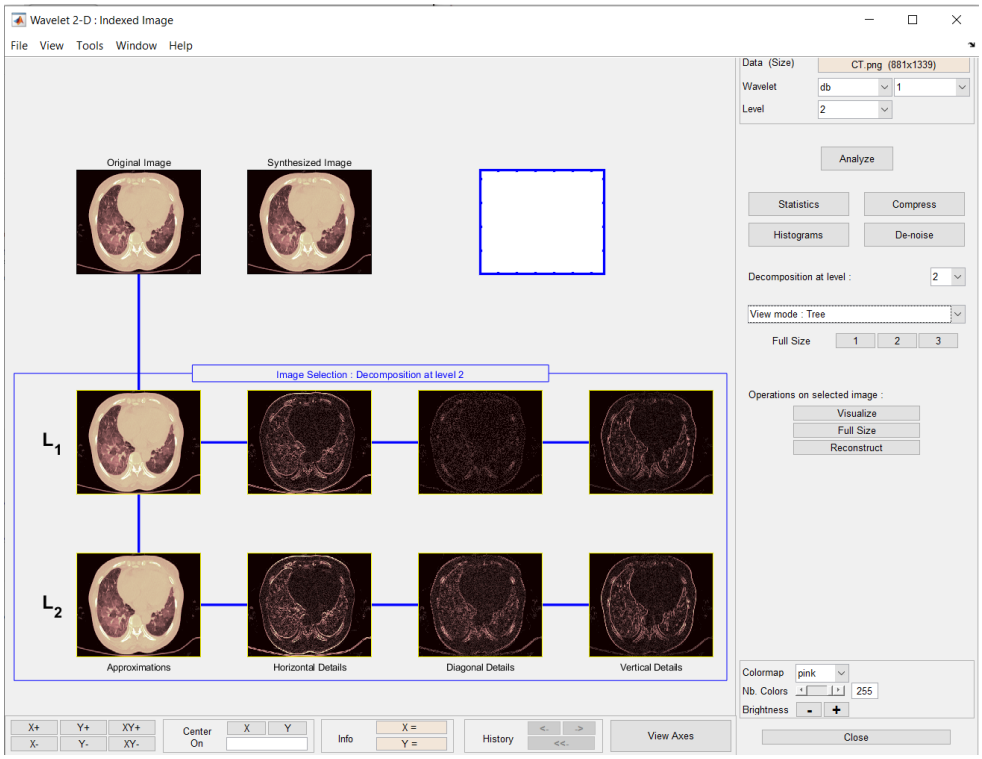
Overall, using the square root of the sparsity norm improves detail retention and energy ratio across all wavelet types, making it preferable for high-quality image decompression.

Using the Wavelet Analyzer toolbox (2-D Wavelet), process the CT Image of Covid-19 using the following wavelets

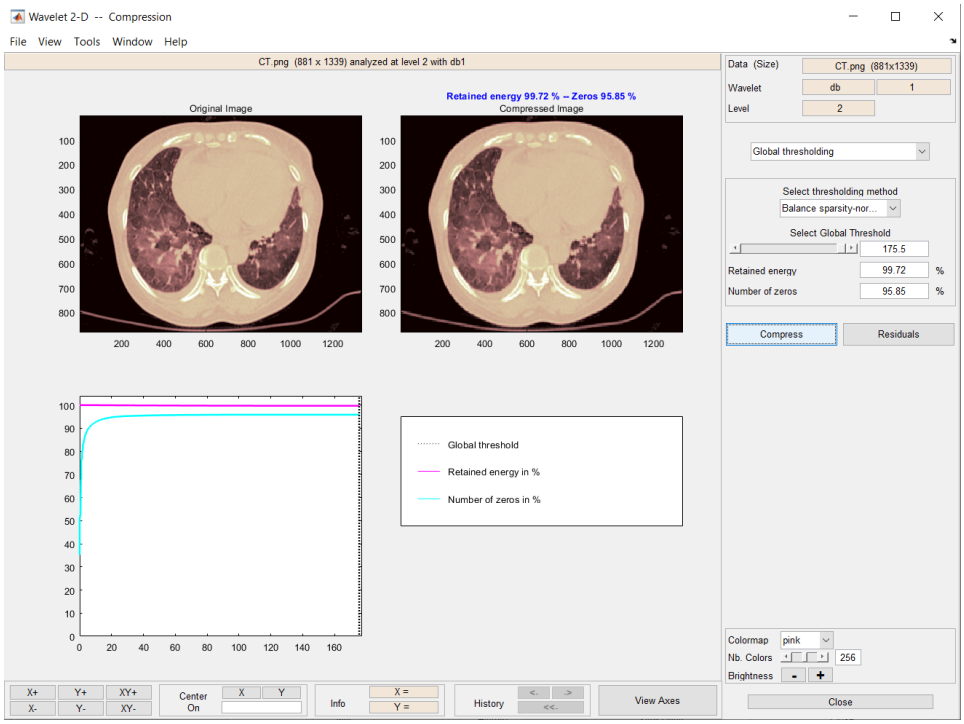
A.db 1 level 2



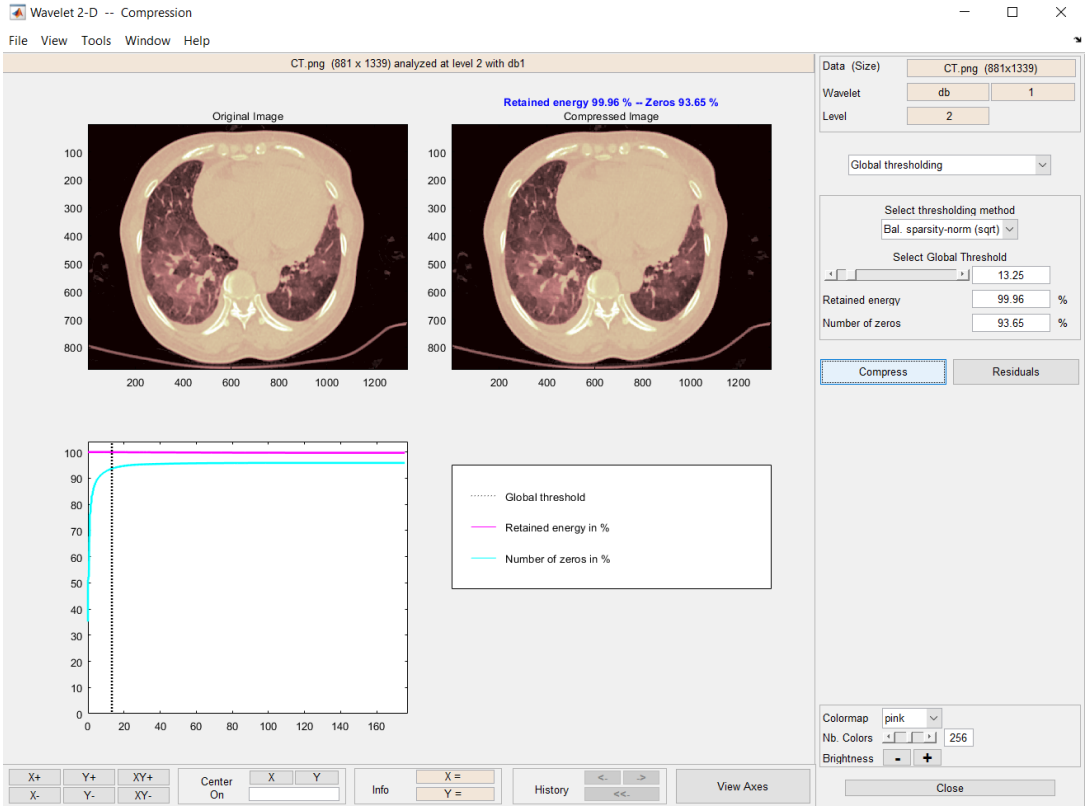
Display the decomposition tree - details and approximations at successive levels of decomposition.



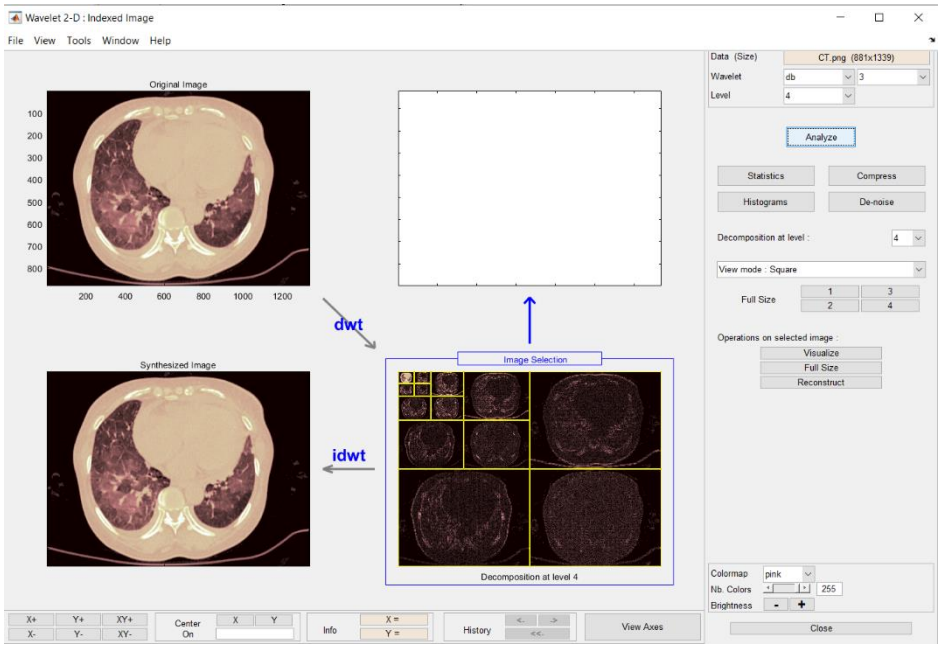
Compress the image using global thresholding with the adopted threshold sparsity-norm



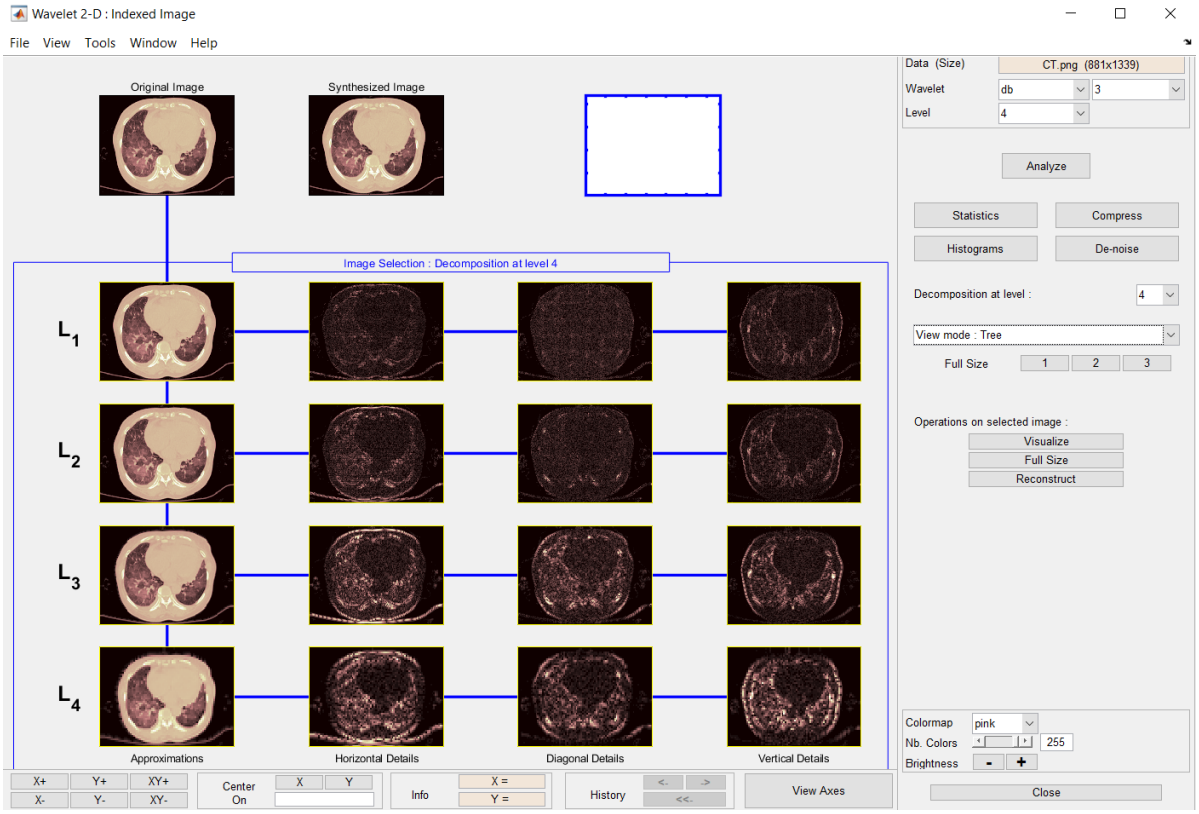
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



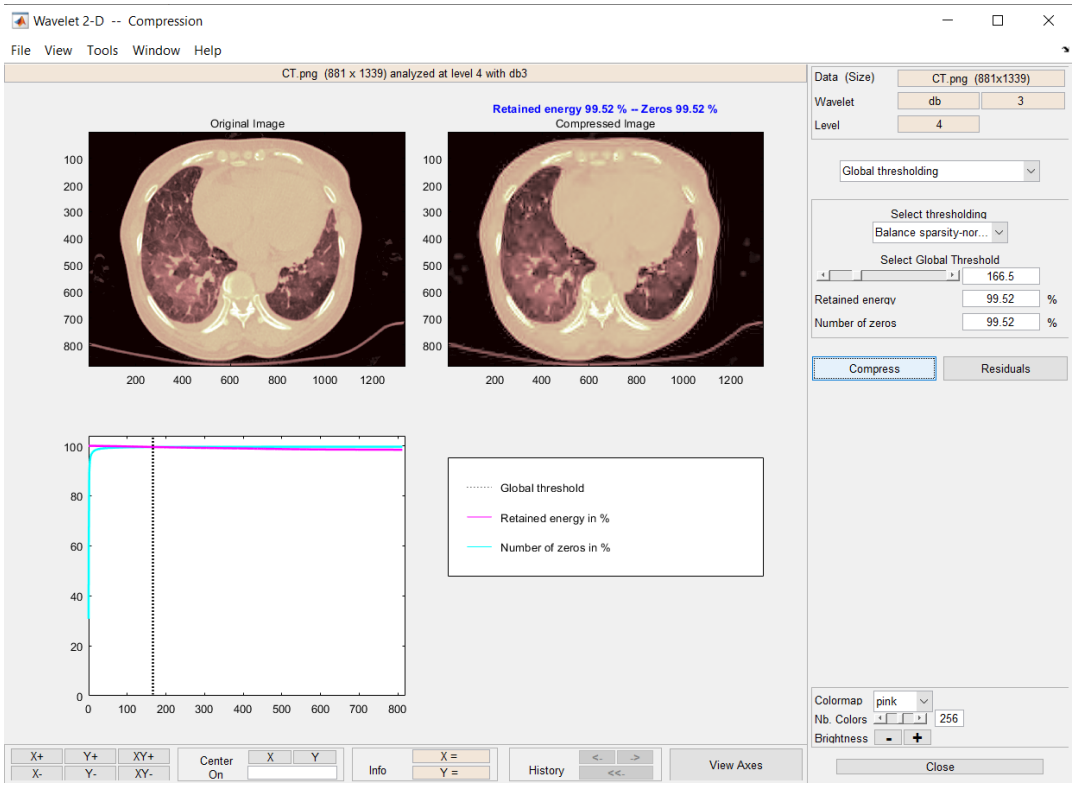
B. db 3 level 4



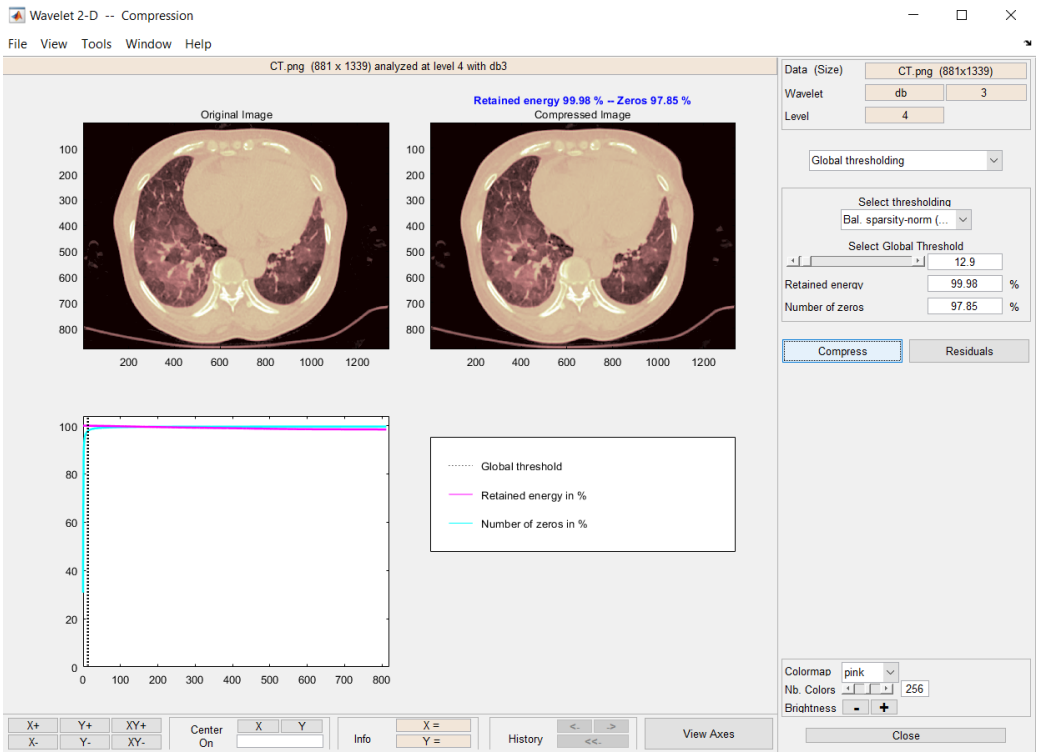
Display the decomposition tree - details and approximations at successive levels of decomposition.



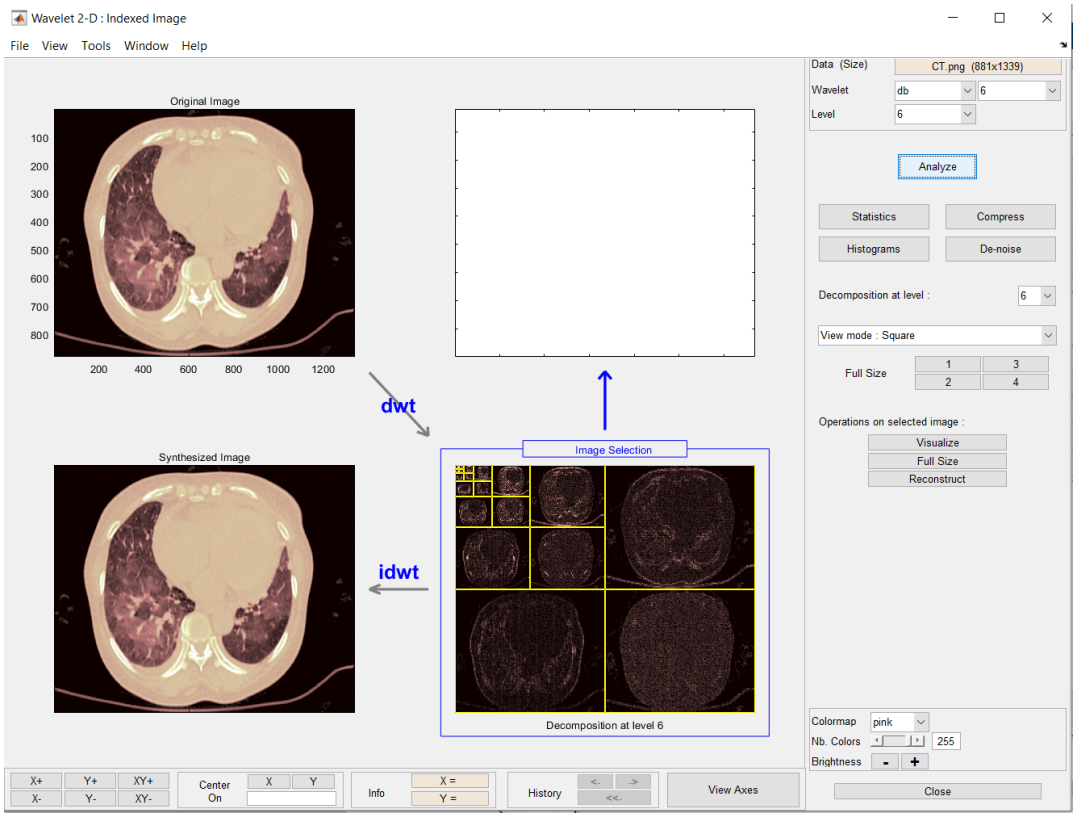
Compress the image using global thresholding with the adopted threshold sparsity-norm



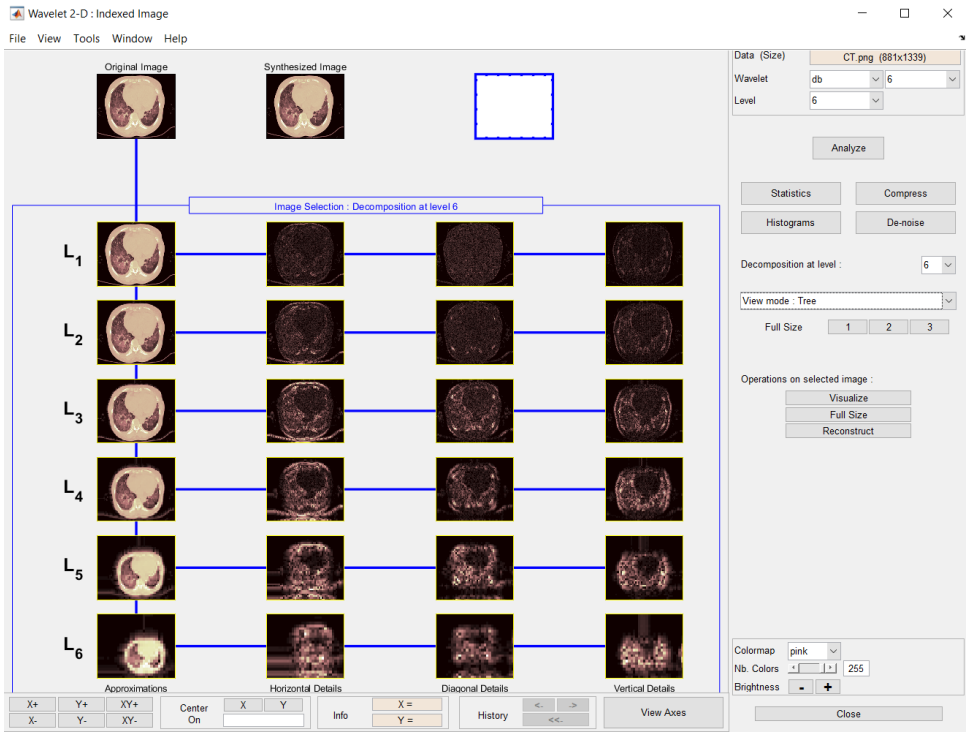
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



C. db 6 level 6

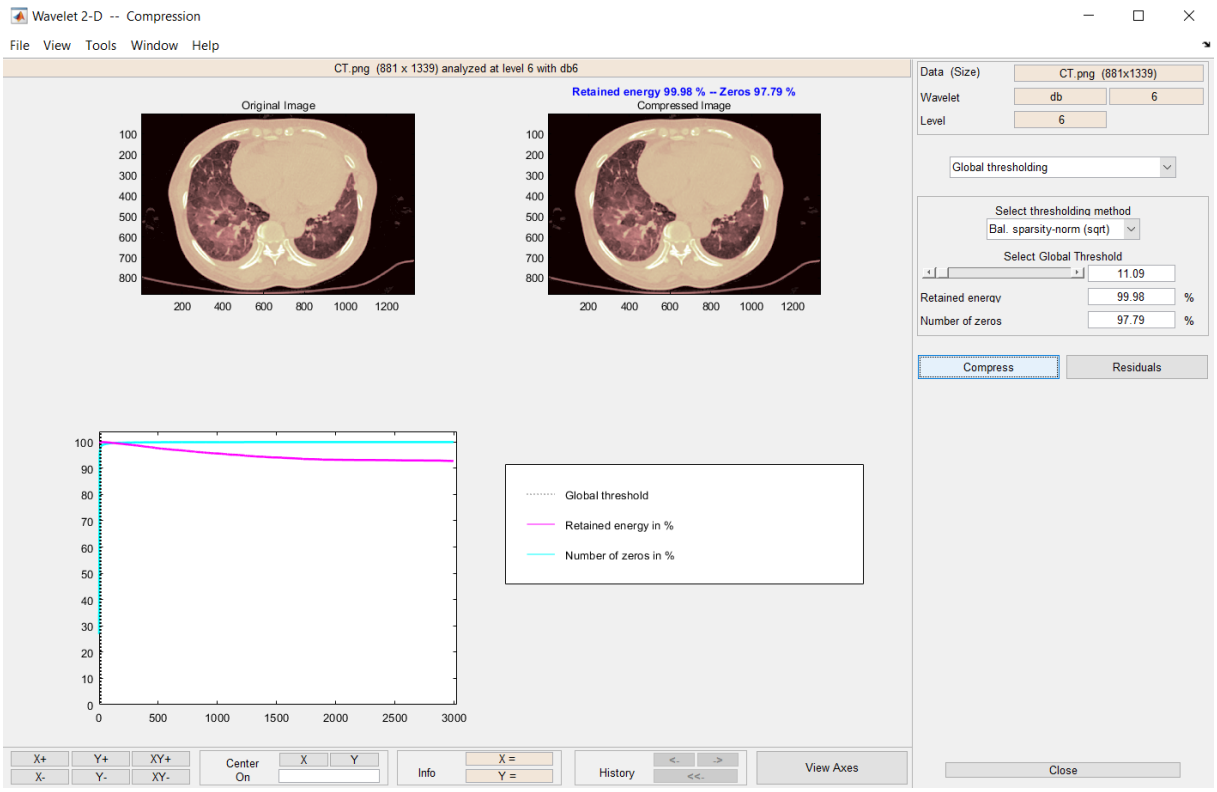


Display the decomposition tree - details and approximations at successive levels of decomposition.

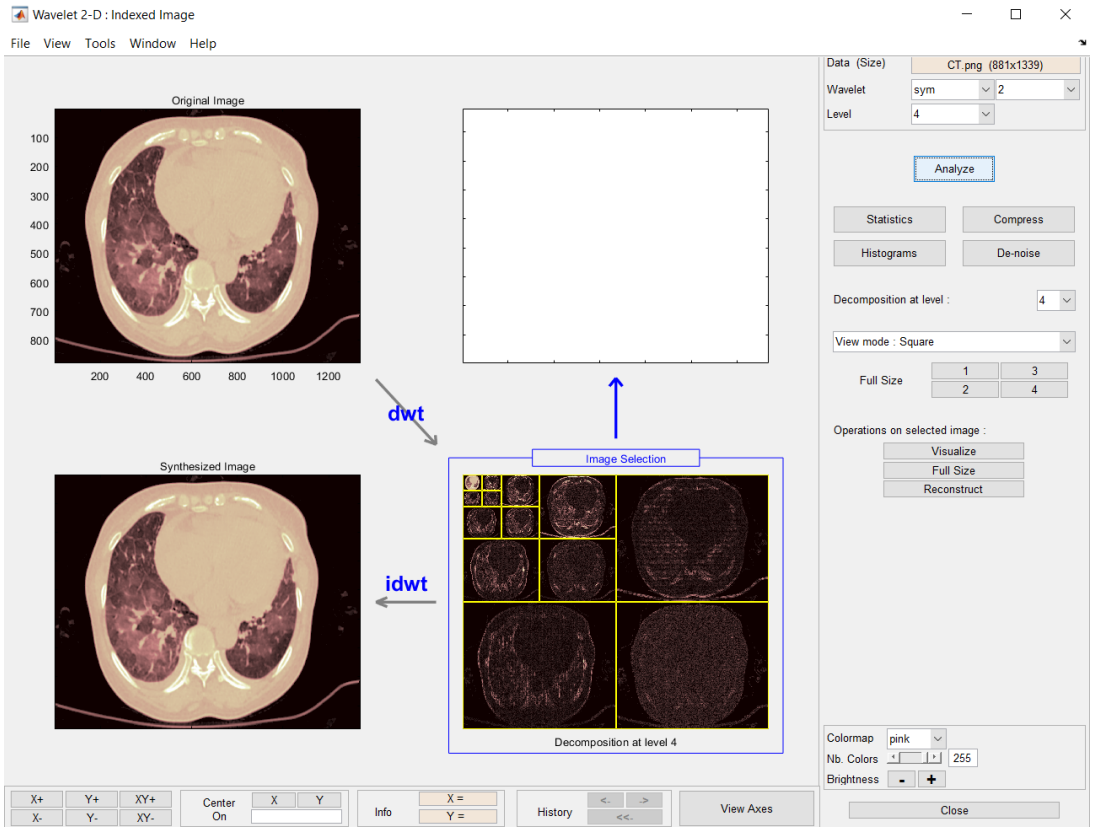


Compress the image using global thresholding with the adopted threshold sparsity-norm

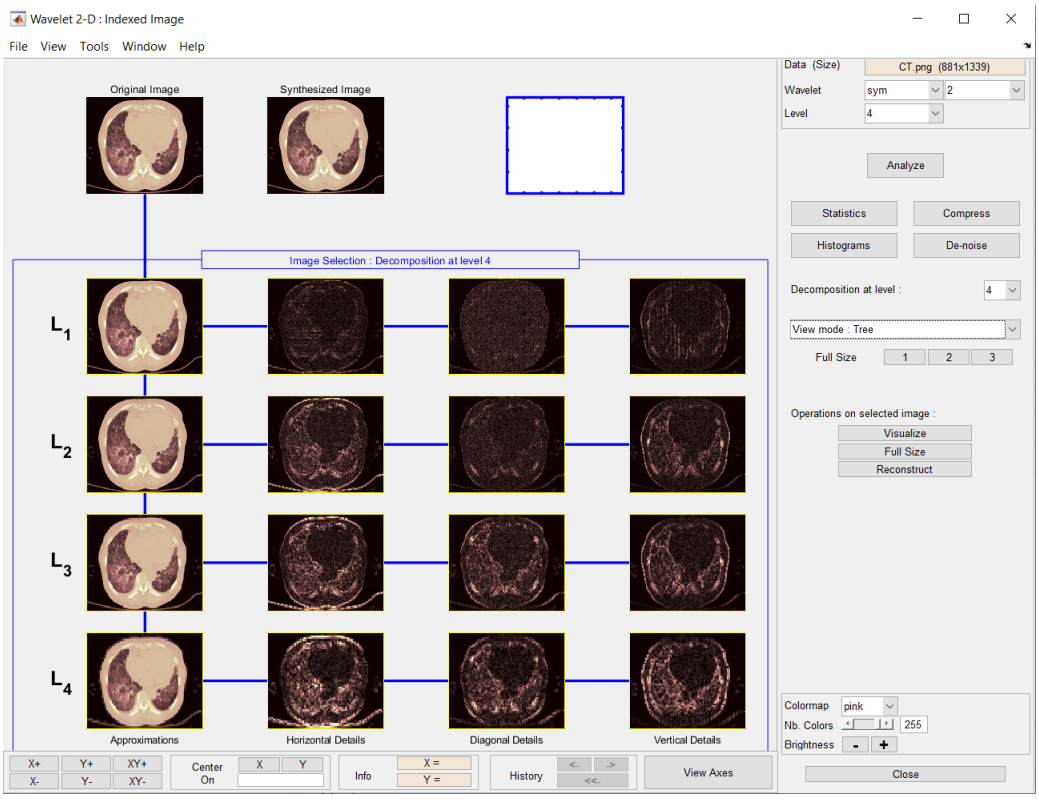
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



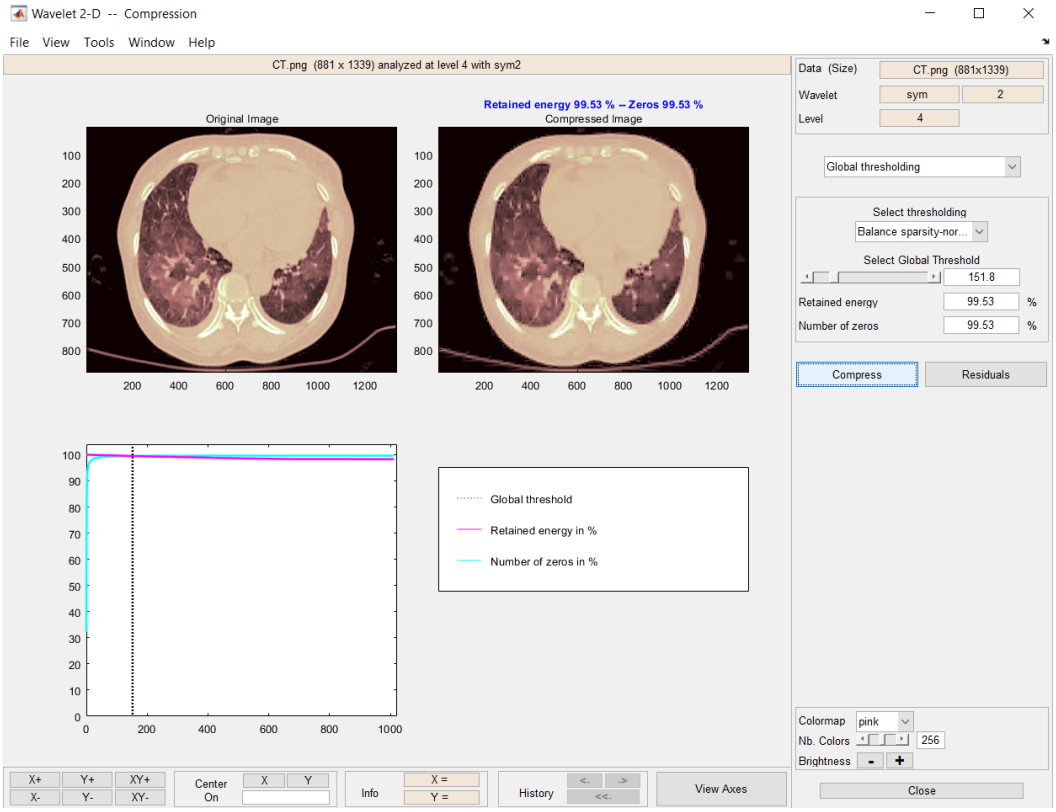
D. sym 2 level 4



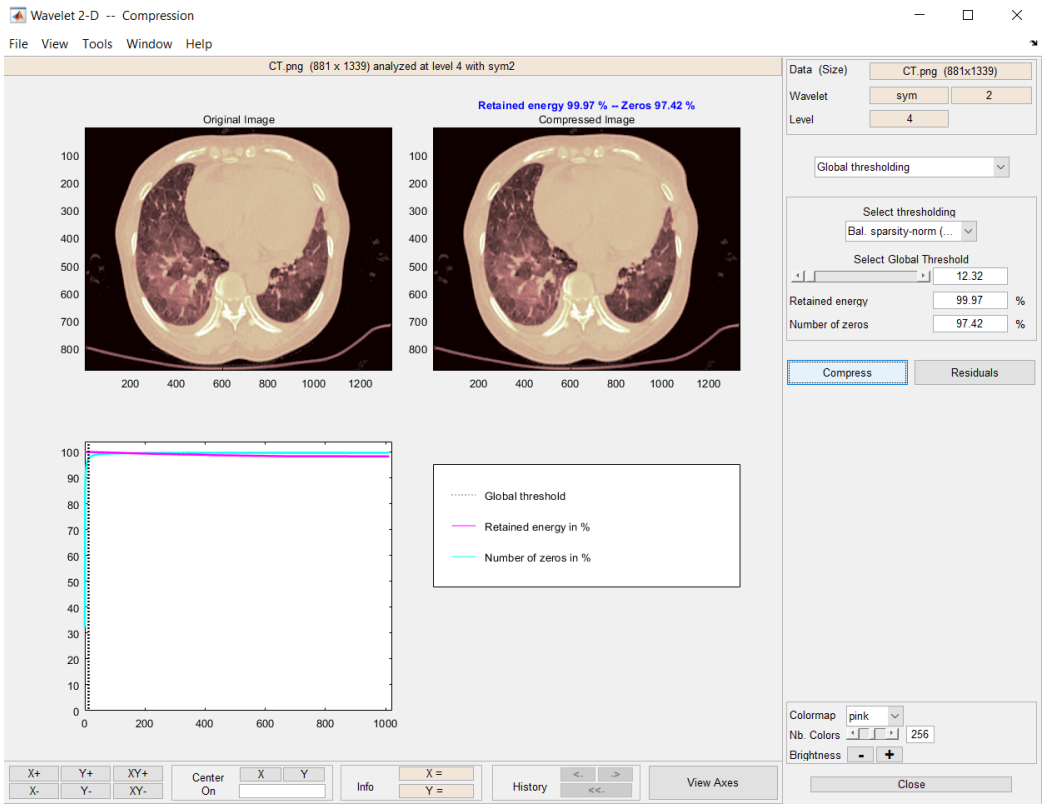
Display the decomposition tree - details and approximations at successive levels of decomposition.



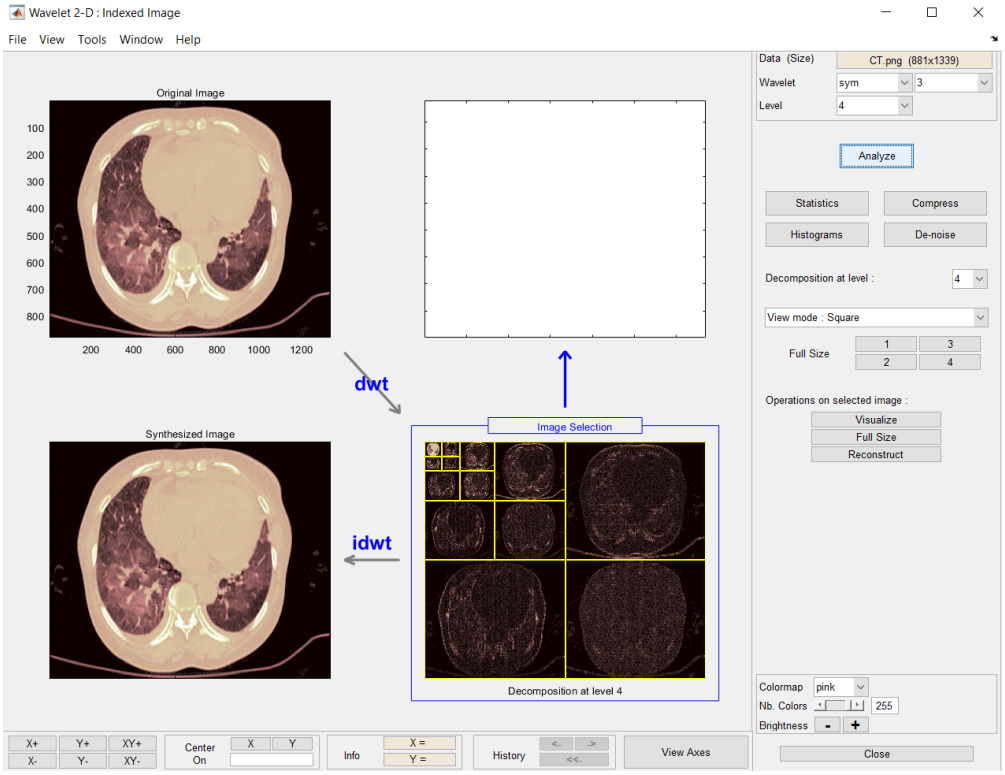
Compress the image using global thresholding with the adopted threshold sparsity-norm



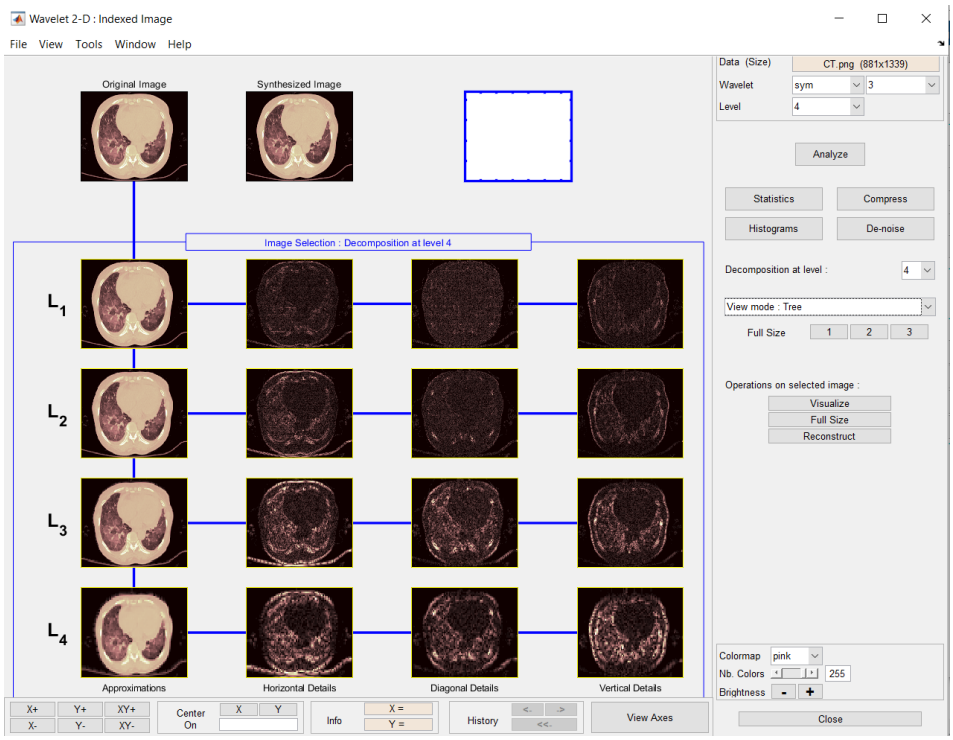
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



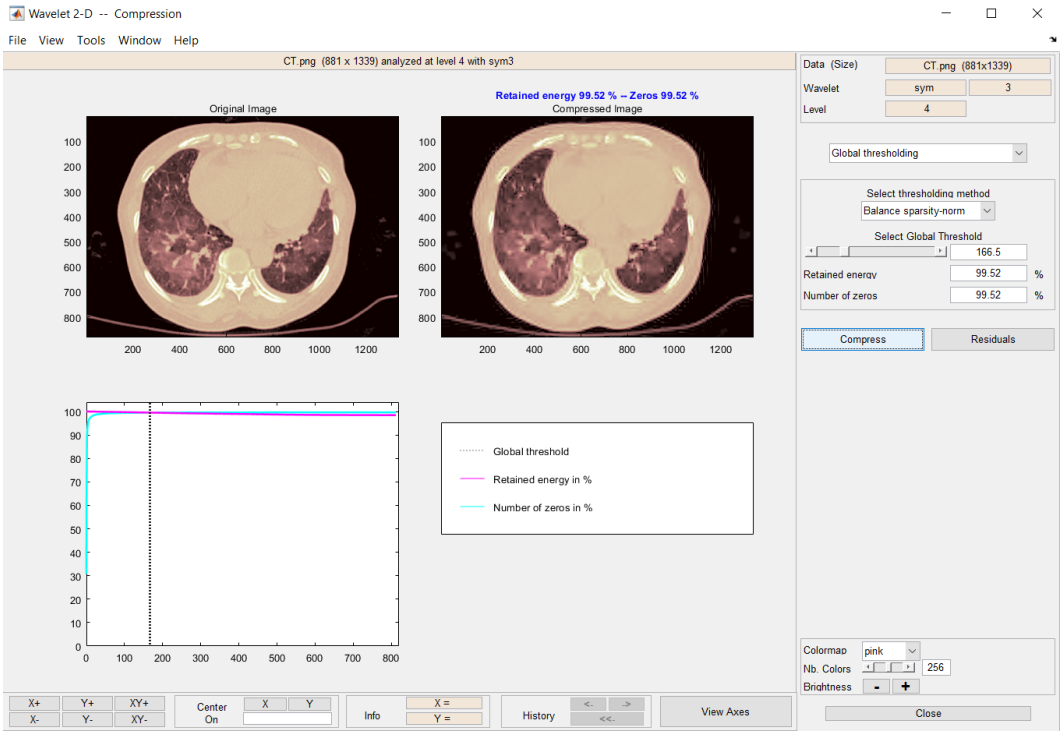
E. sym 3 level 4



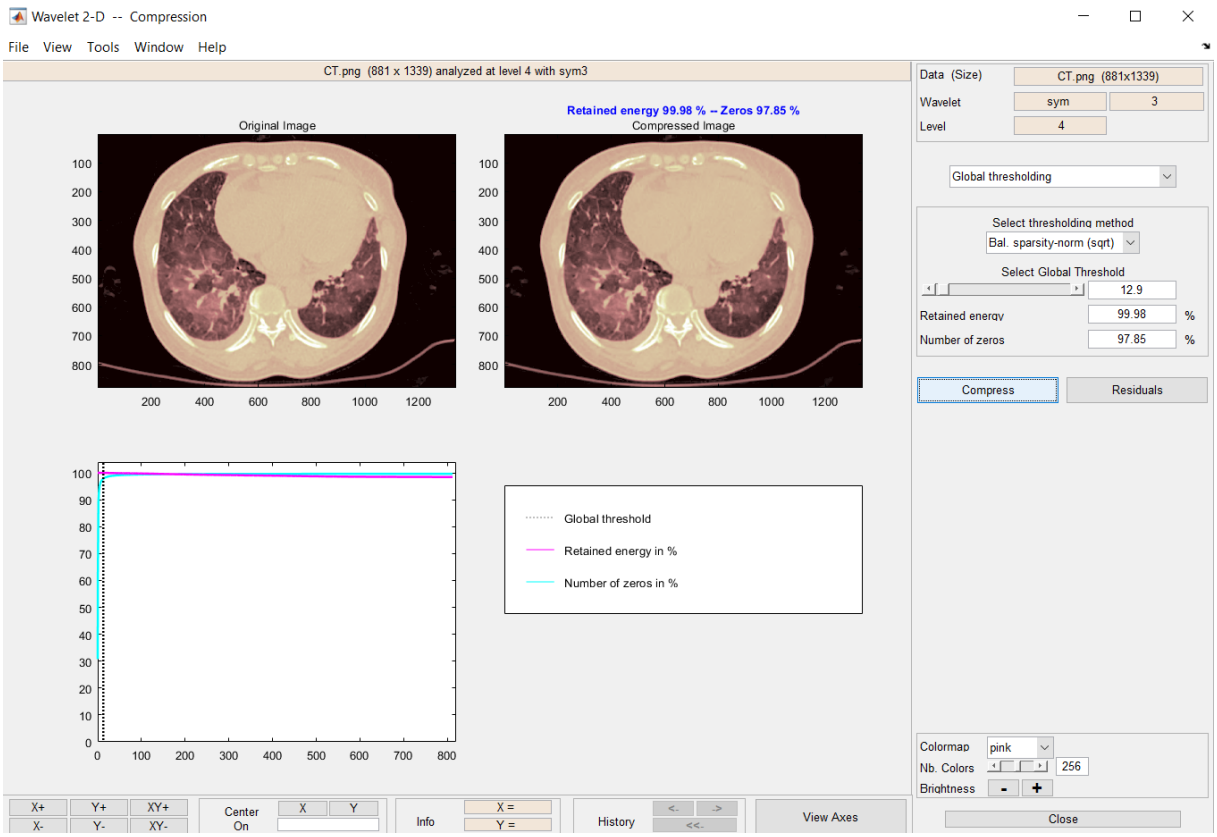
Display the decomposition tree - details and approximations at successive levels of decomposition.



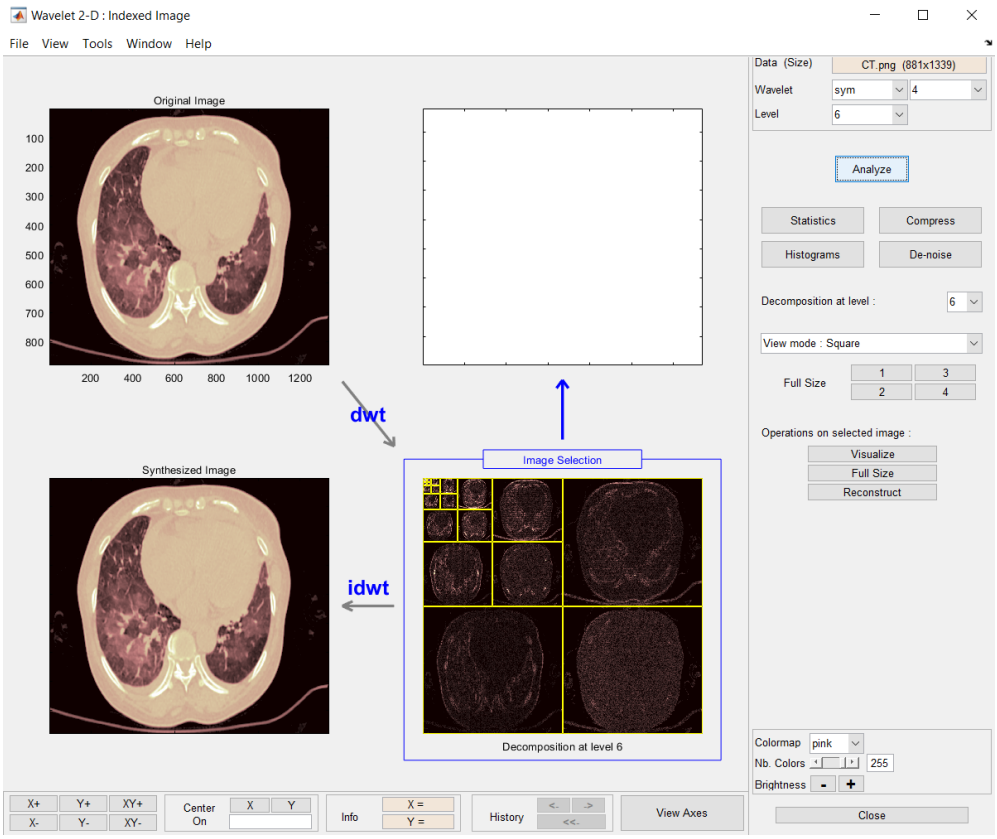
Compress the image using global thresholding with the adopted threshold sparsity-norm



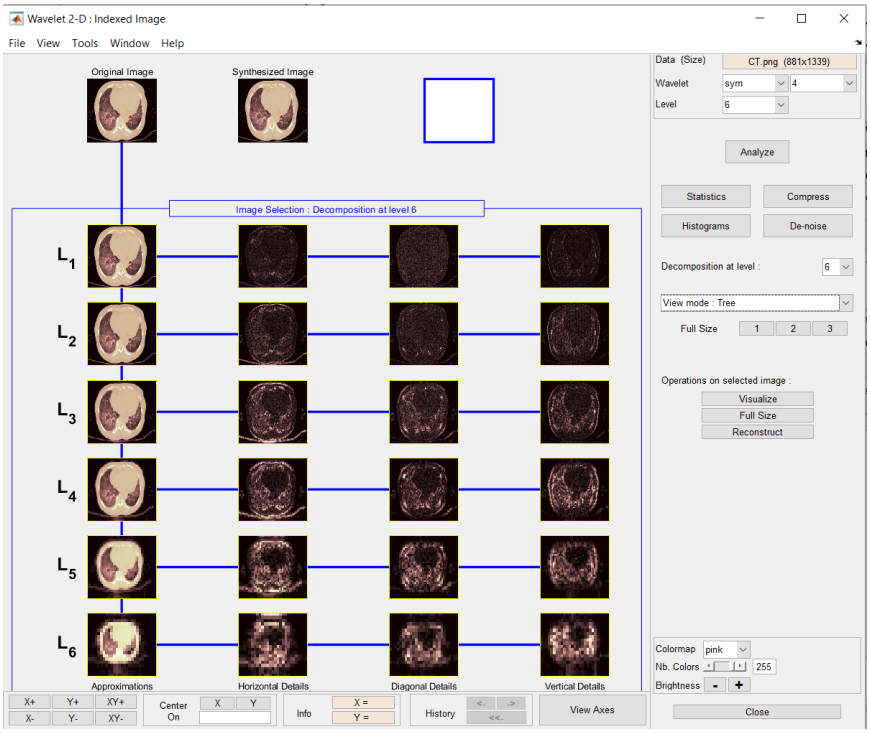
Compress the image using global thresholding with the adopted threshold sparsity-norm(sqrt)



F. sym 4 level 6

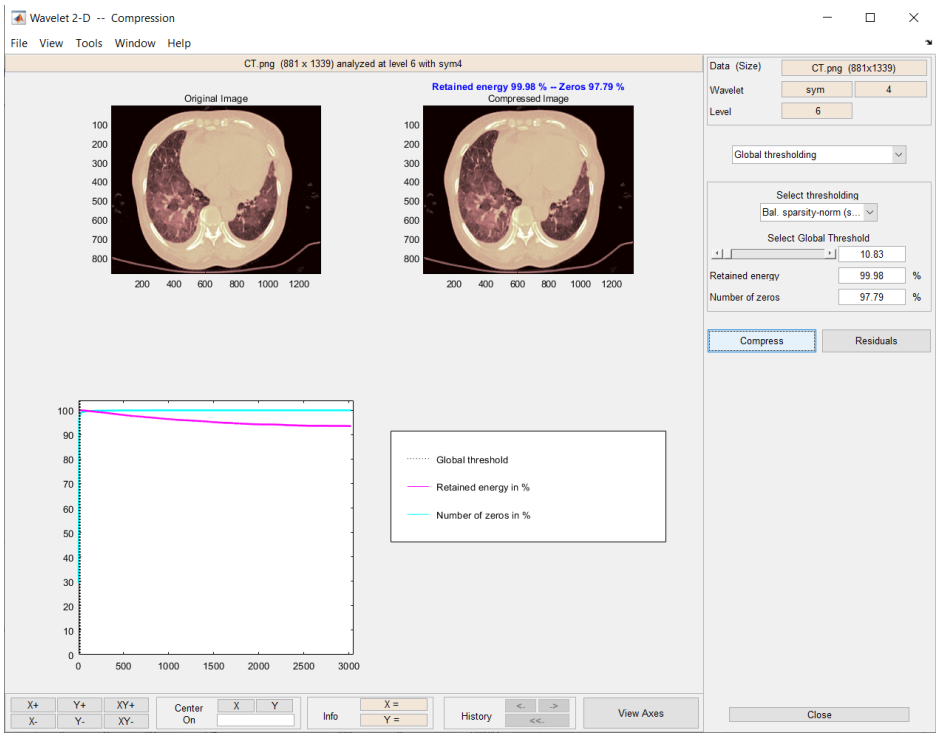


Display the decomposition tree - details and approximations at successive levels of decomposition.

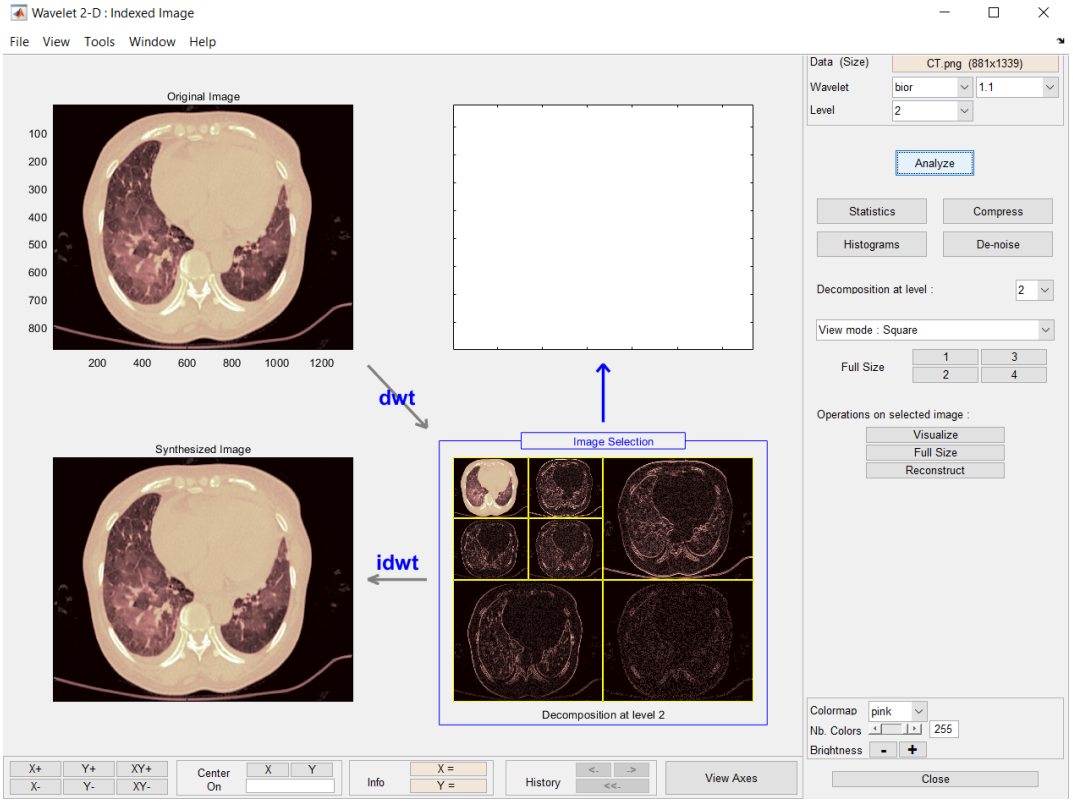


Compress the image using global thresholding with the adopted threshold sparsity-norm

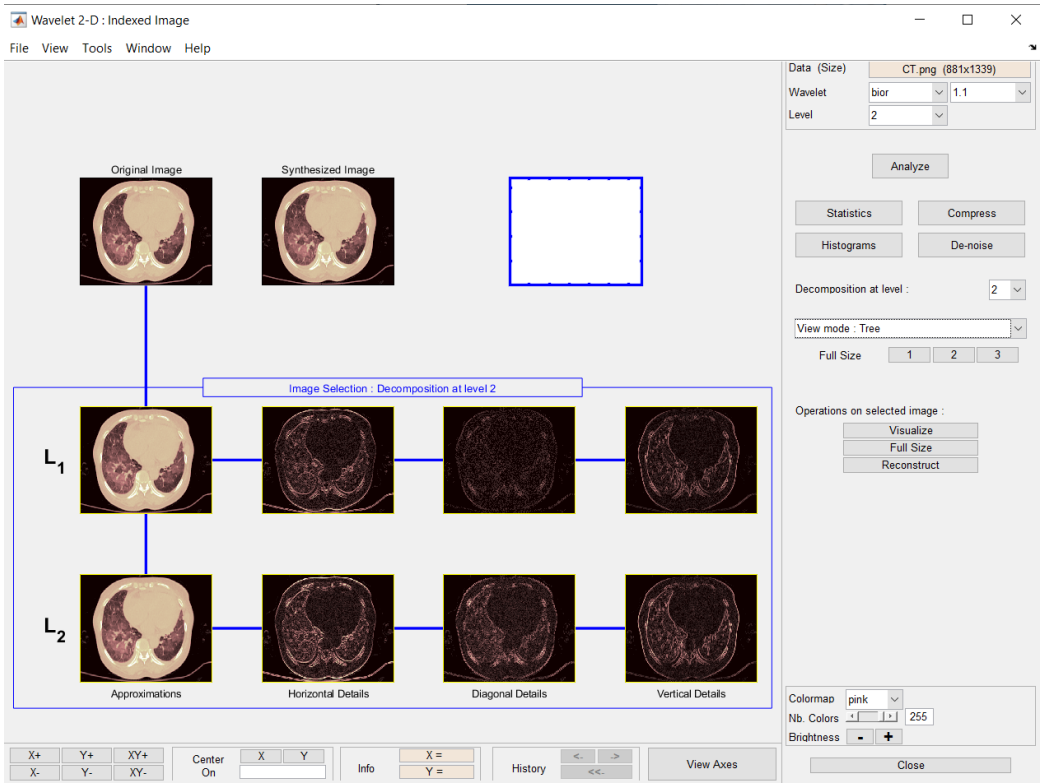
Compress the image using global thresholding with the adopted threshold sparsity-norm(sqrt)



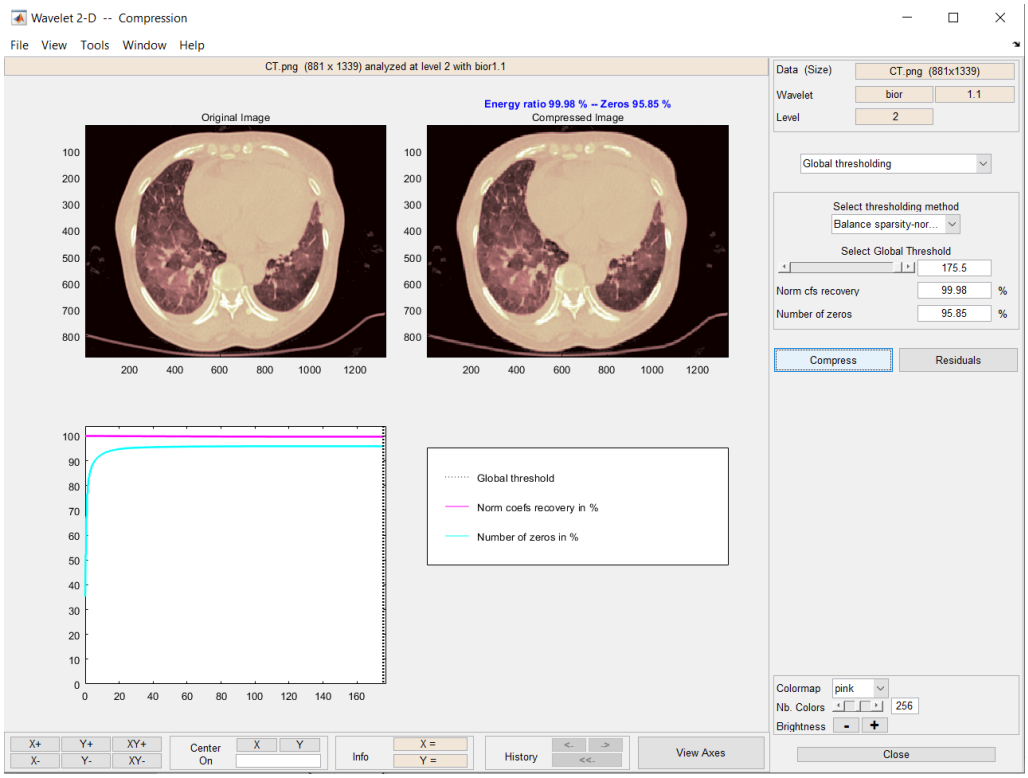
G. bior 1.1: level 2



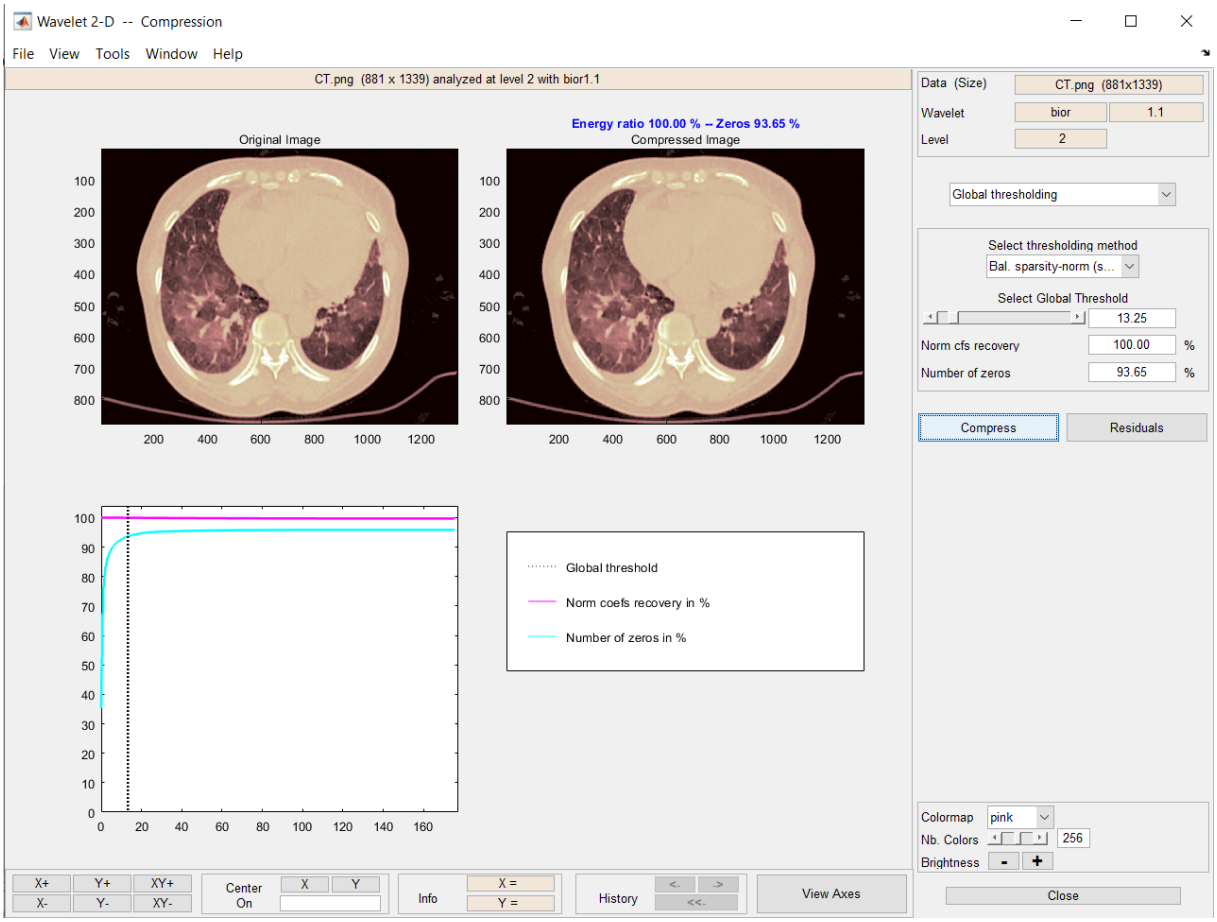
Display the decomposition tree - details and approximations at successive levels of decomposition.



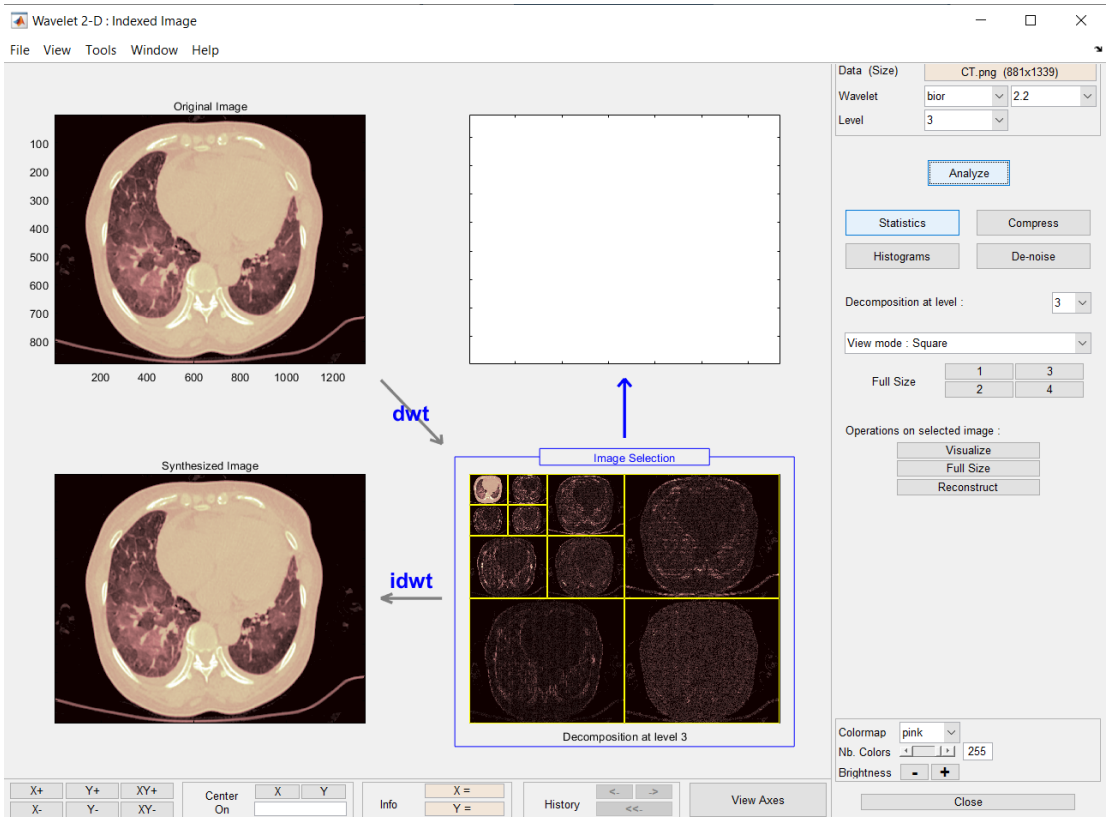
Compress the image using global thresholding with the adopted threshold sparsity-norm



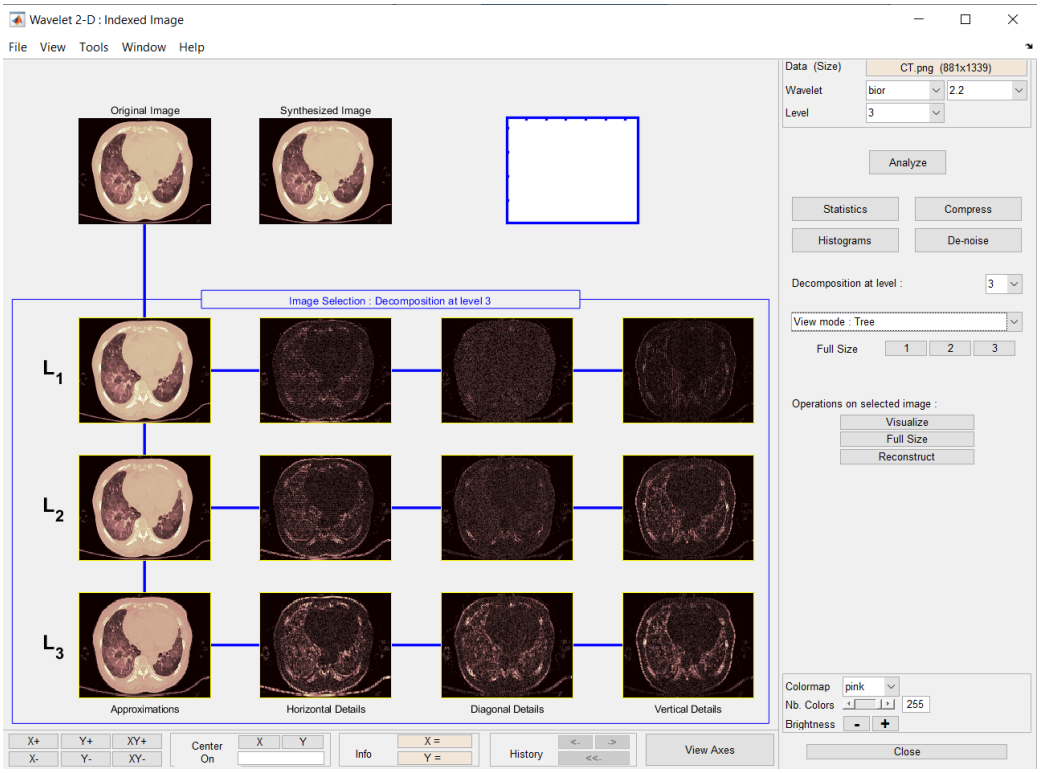
Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



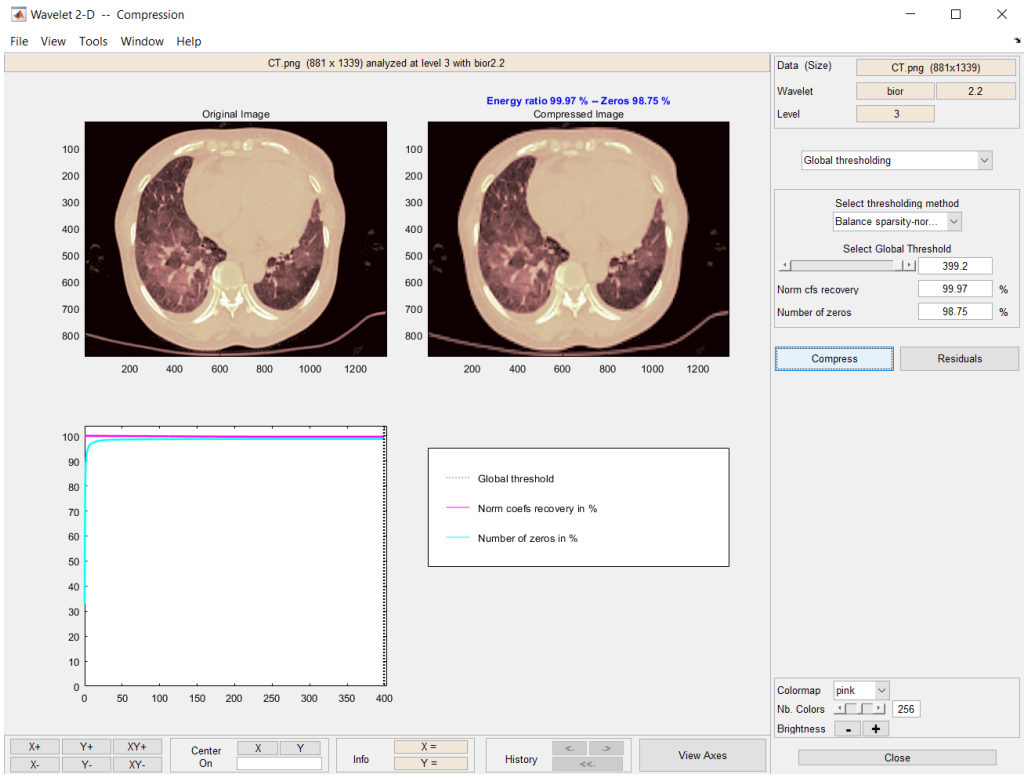
H. bior 2.2: level 3



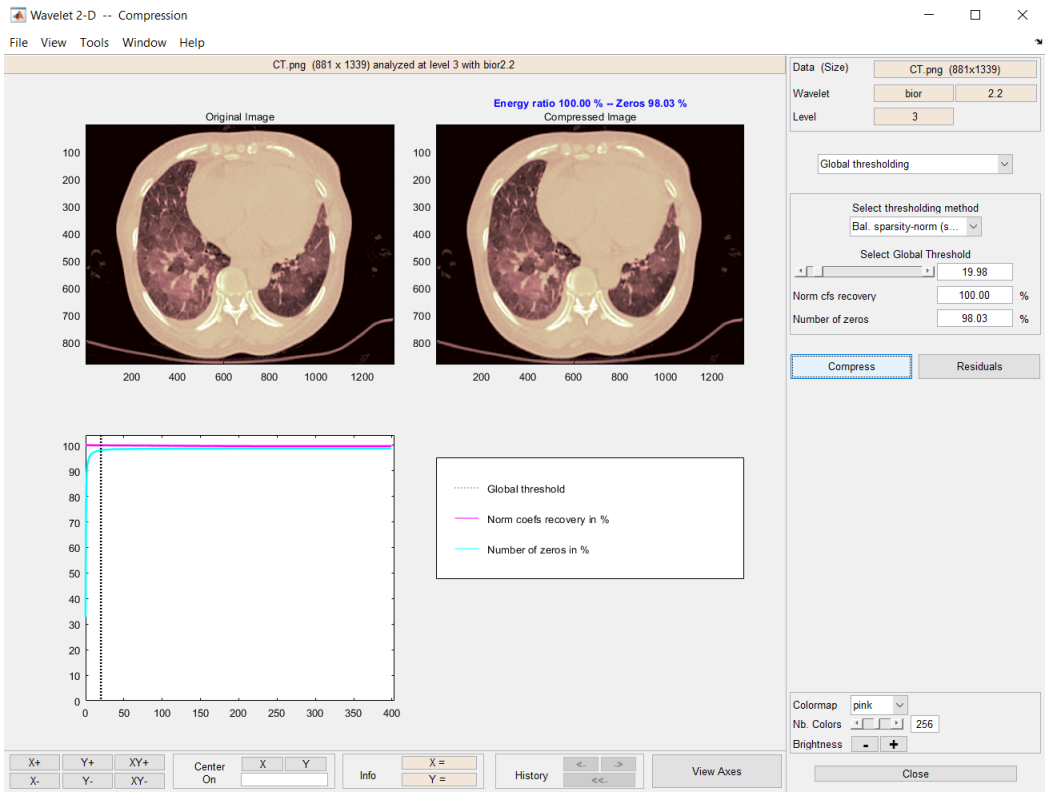
Display the decomposition tree - details and approximations at successive levels of decomposition.



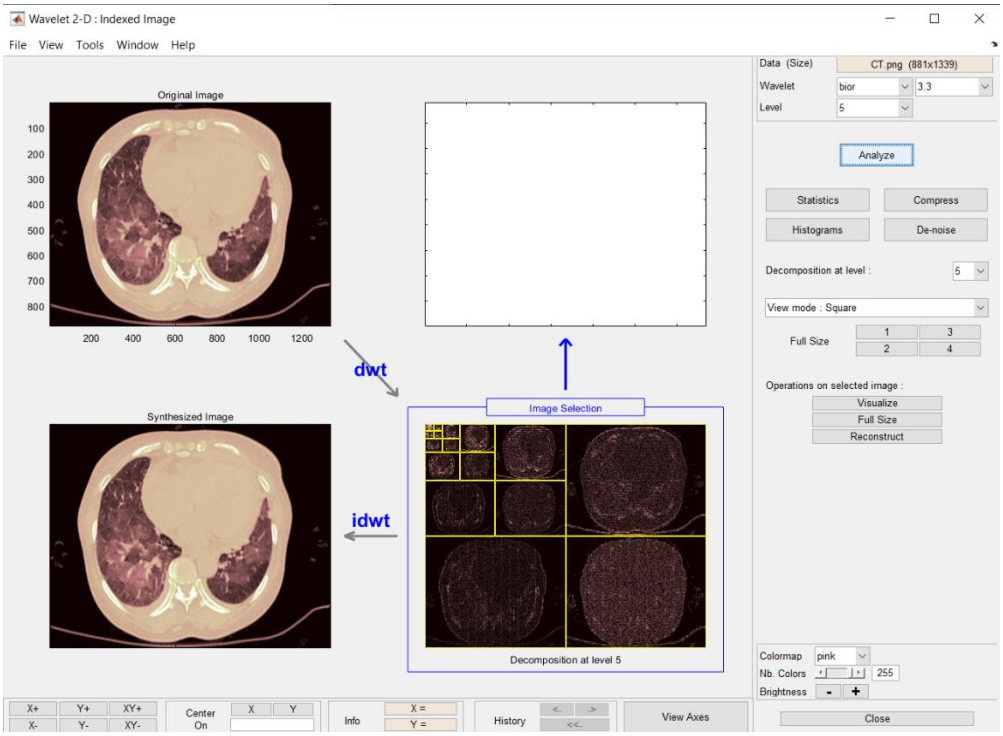
Compress the image using global thresholding with the adopted threshold sparsity-norm



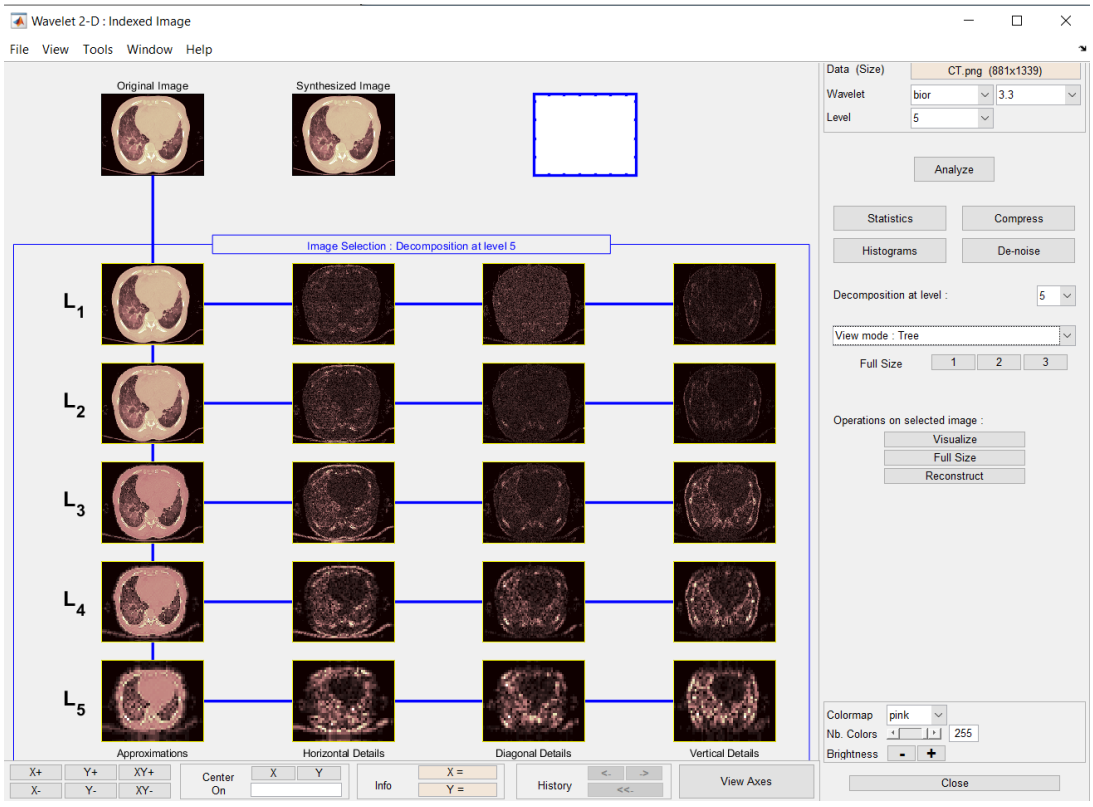
Compress the image using global thresholding with the adopted threshold sparsity-norm(sqrt)



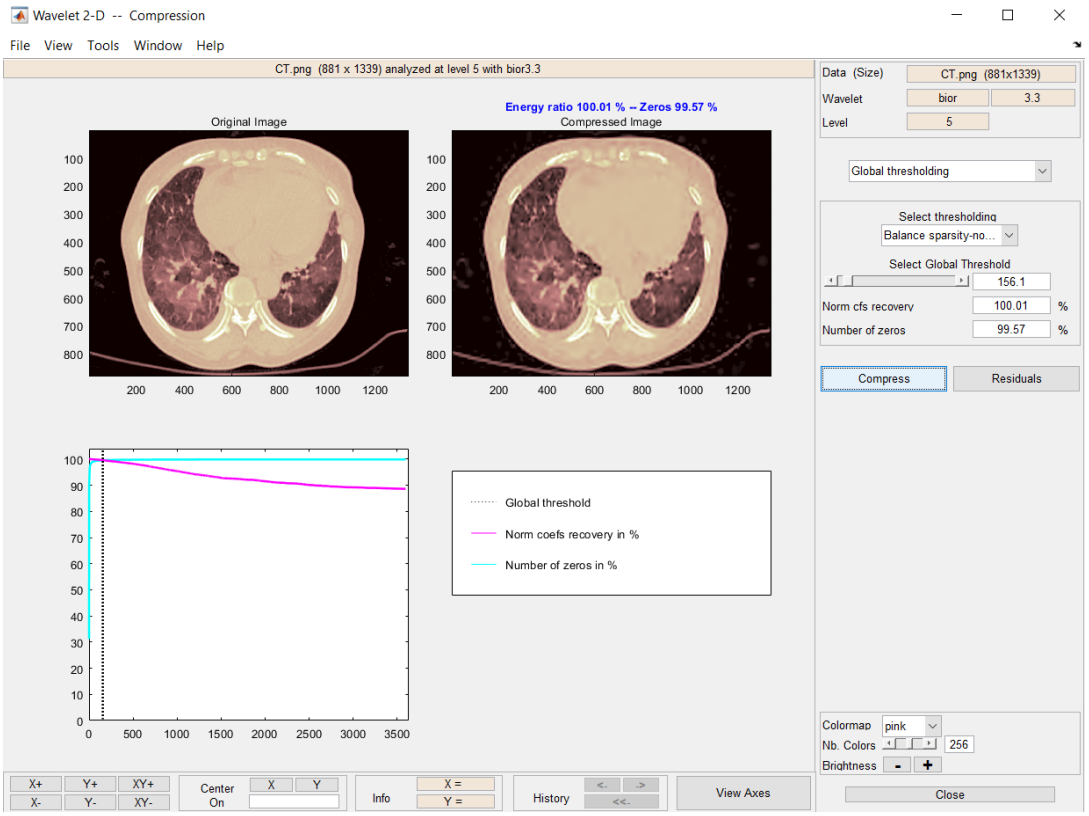
I.bior 3.3: level 5



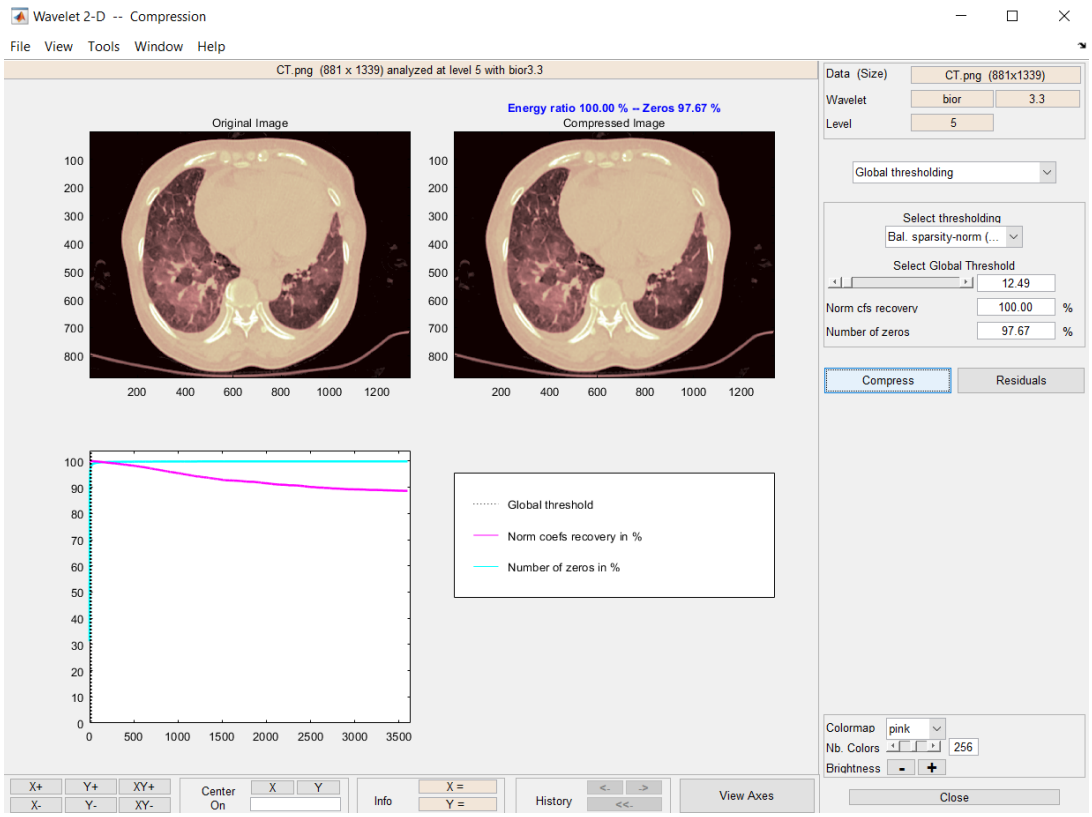
Display the decomposition tree - details and approximations at successive levels of decomposition.



Compress the image using global thresholding with the adopted threshold sparsity-norm



Compress the image using global thresholding with the adopted threshold sparsity norm (sqrt)



Analysis of the obtained results

Wavelet Type	Equal Balance sparsity-norm			Equal Balance sparsity-norm(sqrt)		
	Threshold	Energy ratio (%)	Number of zeroes (%)	Threshold	Energy ratio (%)	Number of zeroes (%)
Db 1 level 2	175.5	99.72	95.85	13.25	99.96	93.65
Db 3 level 4	166.5	99.52	99.52	12.9	99.98	97.85
Db 6 level 6	123.1	99.60	99.60	11.09	99.98	97.79
Sym 2 level 4	151.8	99.53	99.53	12.32	99.97	97.42
Sym 3 level 4	166.5	99.52	99.52	12.9	99.98	97.85
Sym 4 level 6	117.2	99.66	99.66	10.83	99.98	97.79
Bior 1.1 level 2	175.5	99.98	95.85	13.25	100.00	93.65
Bior 2.2 level 3	399.2	99.97	98.75	19.98	100.00	98.03
Bior 3.3 level 5	156.1	100.01	99.57	12.49	100.00	97.67

The table illustrates the impact of wavelet types, levels, and sparsity norms on image compression:

- Db 1 level 2 and Bior 1.1 level 2 show high energy ratios with sparsity-norm but result in more zeroes, indicating lower compression efficiency.

- Using the square root of sparsity-norm, Db 3 level 4 and Sym 3 level 4 maintain high energy ratios and fewer zeroes, balancing compression efficiency and image quality.

- Bior 2.2 level 3 performs best in both energy retention and compression efficiency with sparsity norm (sqrt), making it ideal for high-fidelity applications.

Overall, the square root of the sparsity norm improves compression efficiency while preserving image quality across various wavelet types and levels.

CONCLUSİON

1. Db 1 level 2 and Bior 1.1 level 2: These configurations exhibit high energy ratios with the sparsity-norm method, indicating strong detail retention. However, they also tend to have a high number of zeroes, suggesting lower compression efficiency and more redundancy in the data. While they retain detailed information well, they might not be the most efficient in terms of compression.

2. Square root of the sparsity norm with Db 3 level 4 and Sym 3 level 4: These settings maintain high energy ratios but with fewer zeroes compared to the previous configurations. This balance between compression efficiency and image quality results in effective compression while preserving more of the original image detail. They offer a good compromise between detail retention and compression efficiency.

3. Bior 2.2 level 3 and Bior 3.3 level 5: These wavelet types provide the highest energy retention and compression efficiency with the square root of the sparsity norm. They achieve nearly complete energy retention with minimal zeroes, making them ideal for applications where preserving image quality is paramount. These configurations are well-suited for high-fidelity applications where maintaining critical details is crucial.

4. Db 6 level 6 and Sym 4 level 6: Demonstrating balanced performance, these configurations maintain good energy ratios and a moderate number of zeroes. They offer a solid trade-off between compression efficiency and image quality, making them suitable for general-purpose applications where a compromise between the two is acceptable.

Overall, utilizing the square root of the sparsity norm enhances compression efficiency while preserving image quality across various wavelet types and levels. This approach is advantageous for high-quality image decompression, ensuring critical image details are retained while optimizing the compression process. It's particularly useful for applications requiring both high fidelity and efficient data storage, providing a versatile solution for a range of imaging needs.