

# Performance Analysis of the Members of Coiflet Wavelet Family at successive levels of Image Compression using Discrete Wavelet Transform

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**Abstract---** Image processing using wavelets is one of the most promising areas of research. Different types of wavelet families such as Daubechies, Symlet, Coiflet, and Biorthogonal have been developed and each family has been used in the context of Image compression. The present work analyzes the performance of the members of coiflet wavelet family (coif1, coi2, coif3, coif4, coif5) at successive levels of Image compression using discrete wavelet transform. Images of different sizes have been considered and then they are compressed at six successive levels using discrete wavelet transform with the members of coiflet wavelet family. Size of the image obtained at each level of compression and time elapsed at each level of compression have been considered as parameters for performance evaluation.

**Index terms---** Image compression, Discrete Wavelet Transform, Coiflet Wavelet Family

## I.INTRODUCTION

Everyday an enormous amount of information is stored, processed and transmitted. As most part of this information is graphical or pictorial in nature, the storage and communication requirements for this information are immense. Hence the need for Image compression arises. Image compression addresses the problem of reducing the amount of data required to represent a digital image with no significant loss of information. Applications that require image compression include Internet, Businesses, Multimedia, Satellite Imaging and Medical Imaging. Image compression techniques can be classified in to two types. They are Lossless Image compression techniques and Lossy Image compression techniques. Lossless image compression techniques include variable length coding, LZW coding, Predictive coding etc. Lossy Image compression techniques include transform coding, wavelet coding etc.

A wavelet is a waveform of effectively limited duration that has an average value of zero. Wavelet analysis produces a time-scale view of the signal. Wavelet transform decomposes a signal in to a set of basis functions called wavelets. Depending upon the set of scales and positions at which a wavelet transform operates, they are classified into Discrete Wavelet Transform and Continuous Wavelet Transform. The continuous wavelet transform is the sum over all time of the signal multiplied by scaled and shifted versions of the wavelet function. The continuous wavelet transform computes wavelet coefficients at every possible scale and position. The discrete wavelet transform computes wavelet coefficients at dyadic scales and positions. The wavelet decomposition consists of calculating a

resemblance index between the signal and the wavelet located at position  $b$  and of scale  $a$ . If the index is large, the resemblance is strong, otherwise it is slight. The indexes  $C(a, b)$  are called coefficients. The continuous wavelet transform is mathematically represented by the following equation

$$C(a, b) = \int_{\mathbb{R}} s(t) \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right) dt \quad \text{Where}$$

$a \in \mathbb{R}^+ - \{0\}, b \in \mathbb{R}$ . The discrete wavelet transform is mathematically represented as

$$C(a, b) = \int_{\mathbb{R}} s(t) \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right) dt \quad \text{Where}$$

$a = 2^j, b = k.2^j$  and  $j, k \in \mathbb{Z}^2$ . Typical applications of wavelet transforms include Compression, Noise Reduction, Watermarking, Image edge detection etc.

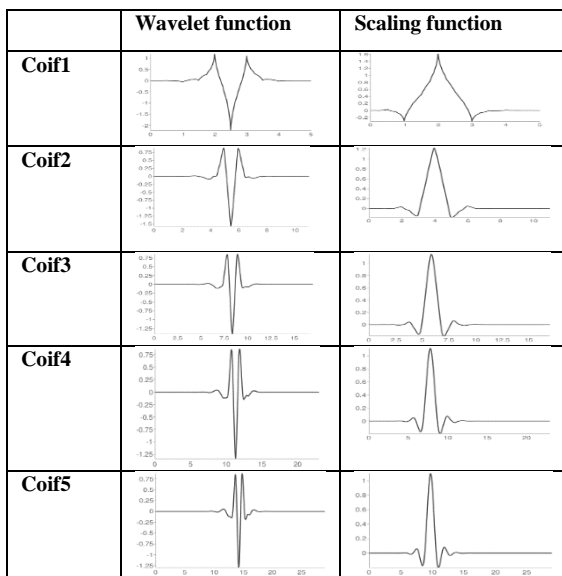
Different families of wavelets such as Daubechies wavelet family, Symlet wavelet family, Coiflet wavelet family, Biorthogonal wavelet family and Reverse Biorthogonal wavelet family have been developed. Each family differs from other depending upon certain characteristics such as Compact support, Symmetry, Regularity, Support width, Number of vanishing moments etc. The Coiflet wavelet family was developed by I. Daubechies at the request of R. Coifman. These are compactly supported wavelets with highest number of vanishing moments for both wavelet function and scaling function for a given support width.

TABLE 1: CHARACTERISTICS OF COIFLET WAVELET

TABLE 2: WAVELET FUNCTION AND SCALING FUNCTION

Family	Coiflet	Compact Support	Yes
Short name	coif	Support Width	6N-1
Order N	N=1,2,3,4,5	Filter Length	6N
Orthogonal	yes	Regularity	-
Biorthogonal	yes	Symmetry	Near from
DWT	possible	Number of Vanishing Moments for PSI	2N
CWT	possible	Number of Vanishing Moments for PHI	2N-1

OF THE MEMBERS OF COIFLET WAVELET FAMILY



II. EXPERIMENTAL WORK AND RESULTS

Images of different sizes have been considered and they are compressed at six successive levels using discrete wavelet transform with the members of coiflet wavelet family. The sizes of the images obtained at each level of compression have been tabulated for analyzing the change of size in each level of compression. The time elapsed for compression at each level has also been tabulated for analysis of time at each level.

TABLE 3: ANALYSIS OF THE SIZE OF THE IMAGES WHICH WERE OBTAINED AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH THE 'COIF1' MEMBER OF COIFLET WAVELET FAMILY

	Image-1	Image-2	Image-3
Size of the original Image	150×200×3	218×220×3	241×250×3
Size of the Image obtained after one level of compression	77×102	111×112	123×127
Size of the Image obtained after two levels of compression	41×53	58×58	64×66
Size of the Image obtained after three levels of compression	23×29	31×31	34×35
Size of the Image obtained after four levels of compression	14×17	18×18	19×20
Size of the Image obtained after five levels of compression	9×11	11×11	12×12
Size of the Image obtained after six levels of compression	7×8	8×8	8×8

TABLE 3: CONTINUED

	Image-4	Image-5
Size of the original Image	527×300×3	463×400×3
Size of the Image obtained after one level of compression	266×152	234×202
Size of the Image obtained after two levels of compression	135×78	119×103
Size of the Image obtained after three levels of compression	70×41	62×54
Size of the Image obtained after four levels of compression	37×23	33×29
Size of the Image obtained after five levels of compression	21×14	19×17
Size of the Image obtained after six levels of compression	13×9	12×11

TABLE 4: ANALYSIS OF THE SIZE OF THE IMAGES WHICH WERE OBTAINED AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH THE ‘COIF2’ MEMBER OF COIFLET WAVELET FAMILY

	Image-1	Image-2	Image-3
Size of the original Image	150×200×3	218×220×3	241×250×3
Size of the Image obtained after one level of compression	80×105	114×115	126×130
Size of the Image obtained after two levels of compression	45×58	62×63	68×70
Size of the Image obtained after three levels of compression	28×34	36×37	39×40
Size of the Image obtained after four levels of compression	19×22	23×24	25×25
Size of the Image obtained after five levels of compression	15×16	17×17	18×18
Size of the Image obtained after six levels of compression	13×13	14×14	14×14

TABLE 4: CONTINUED

	Image-4	Image-5
Size of the original Image	527×300×3	463×400×3
Size of the Image obtained after one level of compression	269×155	237×205
Size of the Image obtained after two levels of compression	140×83	124×108
Size of the Image obtained after three levels of compression	75×47	67×59
Size of the Image obtained after four levels of compression	43×29	39×35
Size of the Image obtained after five levels of compression	27×20	25×23
Size of the Image obtained	19×15	18×17

after six levels of compression		
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TABLE 5: ANALYSIS OF THE SIZE OF THE IMAGES WHICH WERE OBTAINED AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH THE ‘COIF3’ MEMBER OF COIFLET WAVELET FAMILY

	Image-1	Image-2	Image-3
Size of the original Image	150×200×3	218×220×3	241×250×3
Size of the Image obtained after one level of compression	83×108	117×118	129×133
Size of the Image obtained after two levels of compression	50×62	67×67	73×75
Size of the Image obtained three levels of compression	33×39	42×42	45×46
Size of the Image obtained after four levels of compression	25×28	29×29	31×31
Size of the Image obtained after five levels of compression	21×22	23×23	24×24
Size of the Image obtained after six levels of compression	19×19	20×20	20×20

TABLE 5: CONTINUED

	Image-4	Image-5
Size of the original Image	527×300×3	463×400×3
Size of the Image obtained after one level of compression	272×158	240×208
Size of the Image obtained after two levels of compression	144×87	128×112
Size of the Image obtained after three levels of compression	80×52	72×64
Size of the Image obtained after four levels of compression	48×34	44×40
Size of the	32×25	30×28

Image obtained after five levels of compression		
Size of the Image obtained after six levels of compression	24×21	23×22

TABLE 6: ANALYSIS OF THE SIZE OF THE IMAGES WHICH WERE OBTAINED AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH THE 'COIF4' MEMBER OF COIFLET WAVELET FAMILY

	Image-1	Image-2	Image-3
Size of the original Image	150×200×3	218×220×3	241×250×3
Size of the Image obtained after one level of compression	86×111	120×121	132×136
Size of the Image obtained after two levels of compression	54×67	71×72	77×79
Size of the Image obtained after three levels of compression	38×45	47×47	50×51
Size of the Image obtained after four levels of compression	30×34	35×35	36×37
Size of the Image obtained after five levels of compression	26×28	29×29	29×30
Size of the Image obtained after six levels of compression	24×25	26×26	26×26

TABLE 6: CONTINUED

	Image-4	Image-5
Size of the original Image	527×300×3	463×400×3
Size of the Image obtained after one level of compression	275×161	243×211
Size of the Image obtained after two levels	149×92	133×117

of compression		
Size of the Image obtained after three levels of compression	86×57	78×70
Size of the Image obtained after four levels of compression	54×40	50×46
Size of the Image obtained after five levels of compression	38×31	36×34
Size of the Image obtained after six levels of compression	30×27	29×28

TABLE 7: ANALYSIS OF THE SIZE OF THE IMAGES WHICH WERE OBTAINED AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH THE 'COIF5' MEMBER OF COIFLET WAVELET FAMILY

	Image-1	Image-2	Image-3
Size of the original Image	150×200×3	218×220×3	241×250×3
Size of the Image obtained after one level of compression	89×114	123×124	135×139
Size of the Image obtained after two levels of compression	59×71	76×76	82×84
Size of the Image obtained after three levels of compression	44×50	52×52	55×56
Size of the Image obtained after four levels of compression	36×39	40×40	42×42
Size of the Image obtained after five levels of compression	32×34	34×34	35×35
Size of the Image obtained after six levels of compression	30×31	31×31	32×32

TABLE 7: CONTINUED

	Image-4	Image-5
Size of the original Image	527×300×3	463×400×3

Size of the Image obtained after one level of compression	278×164	246×214
Size of the Image obtained after two levels of compression	153×96	137×121
Size of the Image obtained after three levels of compression	91×62	83×75
Size of the Image obtained after four levels of compression	60×45	56×52
Size of the Image obtained after five levels of compression	44×37	42×40
Size of the Image obtained after six levels of compression	36×33	35×34

The results obtained in table 3 show that for an image of size  $m \times n$  pixels, the size of the image reduces to  $\left(\left\lceil \frac{m}{2} \right\rceil + 2\right) \times \left(\left\lceil \frac{n}{2} \right\rceil + 2\right)$  pixels at each level of Image compression using discrete wavelet transform with ‘coif1’ member of coiflet family.

The results obtained in table 4 show that for an image of size  $m \times n$  pixels, the size of the image reduces to  $\left(\left\lceil \frac{m}{2} \right\rceil + 5\right) \times \left(\left\lceil \frac{n}{2} \right\rceil + 5\right)$  pixels at each level of Image compression using discrete wavelet transform with ‘coif2’ member of coiflet family.

The results obtained in table 5 show that for an image of size  $m \times n$  pixels, the size of the image reduces to  $\left(\left\lceil \frac{m}{2} \right\rceil + 8\right) \times \left(\left\lceil \frac{n}{2} \right\rceil + 8\right)$  pixels at each level of Image compression using discrete wavelet transform with ‘coif3’ member of coiflet family.

The results obtained in table 6 show that for an image of size  $m \times n$  pixels, the size of the image reduces to  $\left(\left\lceil \frac{m}{2} \right\rceil + 11\right) \times \left(\left\lceil \frac{n}{2} \right\rceil + 11\right)$  pixels at each level of Image compression using discrete wavelet transform with ‘coif4’ member of coiflet family.

The results obtained in table 7 show that for an image of size  $m \times n$  pixels, the size of the image reduces to  $\left(\left\lceil \frac{m}{2} \right\rceil + 14\right) \times \left(\left\lceil \frac{n}{2} \right\rceil + 14\right)$  pixels at each level of Image compression using discrete wavelet transform with ‘coif5’ member of coiflet family.

**TABLE 8: ANALYSIS OF THE TIME ELAPSED FOR IMAGE COMPRESSION AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH ‘COIF1’ MEMBER OF COIFLET FAMILY**

	Image-1	Image-2	Image-3
Time taken for Image compression at level-1 in seconds	0.360000	0.016000	0.015000
Time taken for Image compression at level-2 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000	0.000000

**TABLE 8: CONTINUED**

	Image-4	Image-5
Time taken for Image compression at level-1 in seconds	0.047000	0.063000
Time taken for Image compression at level-2 in seconds	0.015000	0.000000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000

**TABLE 9: ANALYSIS OF THE TIME REQUIRED FOR IMAGE COMPRESSION AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH ‘COIF2’ MEMBER OF COIFLET FAMILY.**

	Image-1	Image-2	Image-3
Time taken for Image compression at level-1 in seconds	0.015000	0.016000	0.016000
Time taken for Image compression at level-2 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000	0.000000

Time taken for Image compression at level-5 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000	0.000000

TABLE 9: CONTINUED

	Image-4	Image-5
Time taken for Image compression at level-1 in seconds	0.078000	0.078000
Time taken for Image compression at level-2 in seconds	0.000000	0.016000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000

TABLE 10: ANALYSIS OF THE TIME ELAPSED FOR IMAGE COMPRESSION AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH ‘COIF3’ MEMBER OF COIFLET FAMILY.

	Image-1	Image-2	Image-3
Time taken for Image compression at level-1 in seconds	0.016000	0.016000	0.031000
Time taken for Image compression at level-2 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000	0.000000

Time taken for Image compression at level-6 in seconds	0.000000	0.000000	0.000000
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TABLE 10: CONTINUED

	Image-4	Image-5
Time taken for Image compression at level-1 in seconds	0.094000	0.109000
Time taken for Image compression at level-2 in seconds	0.016000	0.016000
Time taken for Image compression at level-3 in seconds	0.016000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000

TABLE 11: ANALYSIS OF THE TIME ELAPSED FOR IMAGE COMPRESSION AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH ‘COIF4’ MEMBER OF COIFLET FAMILY.

	Image-1	Image-2	Image-3
Time taken for Image compression at level-1 in seconds	0.015000	0.032000	0.031000
Time taken for Image compression at level-2 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000	0.000000

TABLE 11: CONTINUED

	Image-4	Image-5
Time taken for Image compression at level-1 in seconds	0.484000	0.141000
Time taken for Image compression at level-2 in seconds	0.016000	0.016000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000

TABLE 12: ANALYSIS OF THE TIME ELAPSED FOR IMAGE COMPRESSION AT SIX SUCCESSIVE LEVELS OF IMAGE COMPRESSION USING DISCRETE WAVELET TRANSFORM WITH ‘COIF5’ MEMBER OF COIFLET FAMILY.

	Image-1	Image-2	Image-3
Time taken for Image compression at level-1 in seconds	0.031000	0.031000	0.047000
Time taken for Image compression at level-2 in seconds	0.000000	0.000000	0.016000
Time taken for Image compression at level-3 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000	0.000000

TABLE 12: CONTINUED

	Image-4	Image-5
Time taken for Image compression at level-1 in seconds	0.141000	0.156000
Time taken for Image compression at level-2 in seconds	0.015000	0.032000
Time taken for Image compression at level-3 in seconds	0.015000	0.000000
Time taken for Image compression at level-4 in seconds	0.000000	0.000000
Time taken for Image compression at level-5 in seconds	0.000000	0.000000
Time taken for Image compression at level-6 in seconds	0.000000	0.000000

The results obtained in table 8, table 9, table 10, table 11 and table 12 show that the time taken for Image compression at level-i is less than or equal to the time taken for Image compression at level i-1 for  $2 \leq i \leq 6$  in the context of Image compression using discrete wavelet transform with each member of the coiflet wavelet family.

III.CONCLUSION

Image compression is necessary for storage and transmission of images. Many techniques have been developed for compression of images and discrete wavelet transform is one of the techniques to compress the images. In this paper, a study has been done on the performance evaluation of the members of Coiflet Wavelet family in the context of Image compression using Discrete Wavelet Transform. Images of different sizes have been considered and then they are compressed at six successive levels using the members of Coiflet Wavelet family. The results obtained show that for an image of size  $m \times n$  pixels, the size of the image reduces to

$$\left( \left\lceil \frac{m}{2} \right\rceil + 2 \right) \times \left( \left\lceil \frac{n}{2} \right\rceil + 2 \right) \text{ pixels,}$$

$$\left( \left\lceil \frac{m}{2} \right\rceil + 5 \right) \times \left( \left\lceil \frac{n}{2} \right\rceil + 5 \right) \text{ pixels, } \left( \left\lceil \frac{m}{2} \right\rceil + 8 \right) \times \left( \left\lceil \frac{n}{2} \right\rceil + 8 \right) \text{ pixels,}$$

$$\left( \left\lceil \frac{m}{2} \right\rceil + 11 \right) \times \left( \left\lceil \frac{n}{2} \right\rceil + 11 \right) \text{ pixels} \quad \text{and}$$

$$\left( \left\lceil \frac{m}{2} \right\rceil + 14 \right) \times \left( \left\lceil \frac{n}{2} \right\rceil + 14 \right) \text{ pixels}$$

at each level of Image compression using discrete wavelet transform with coif1, coif2, coif3, coif4 and coif5 members of coiflet family respectively. It is also obtained that the time taken for compression at level-i is less than or equal to the time taken for compression at level i-1 for  $2 \leq i \leq 6$  in the context

of Image compression using discrete wavelet transform with each member of the coiflet wavelet family.

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