CS517 Digital Image Processing

Assignment 4

LZW Compression

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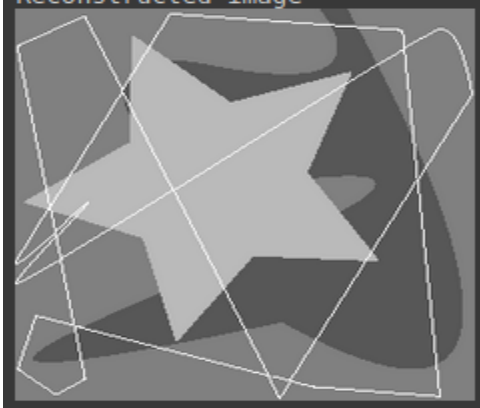
LZW Compression Analysis:

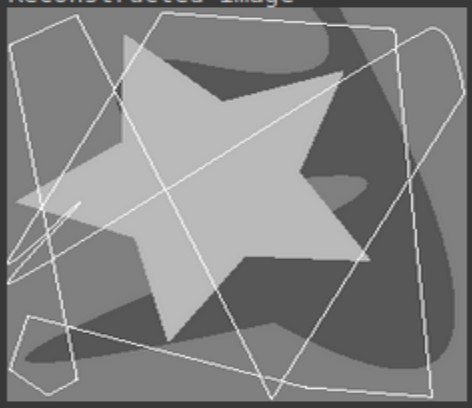
Image : Fig81a.tif

Reconstructed image



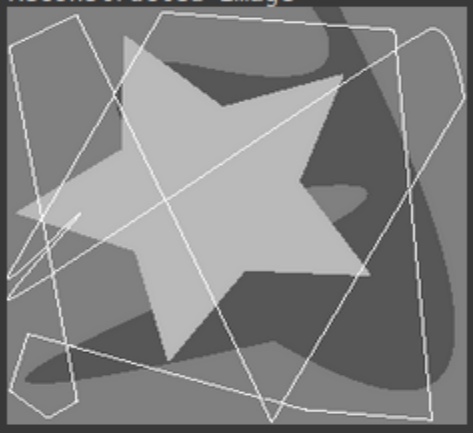
Metric	Value
Compression Ratio (LZW)	4.71
Entropy (LZW)	10.71
Average Encoded Length (LZW)	3.53
Max Value in dictionary	2908
Total Codes Dictionary	2909
Block Size	-1
Code Size	30

Reconstructed image



Metric	Value
Compression Ratio (LZW)	4.71
Entropy (LZW)	2.31
Average Encoded Length (LZW)	2.95
Max Value in dictionary	267
Total Codes Dictionary	1071365
Block Size	4
Code Size	10

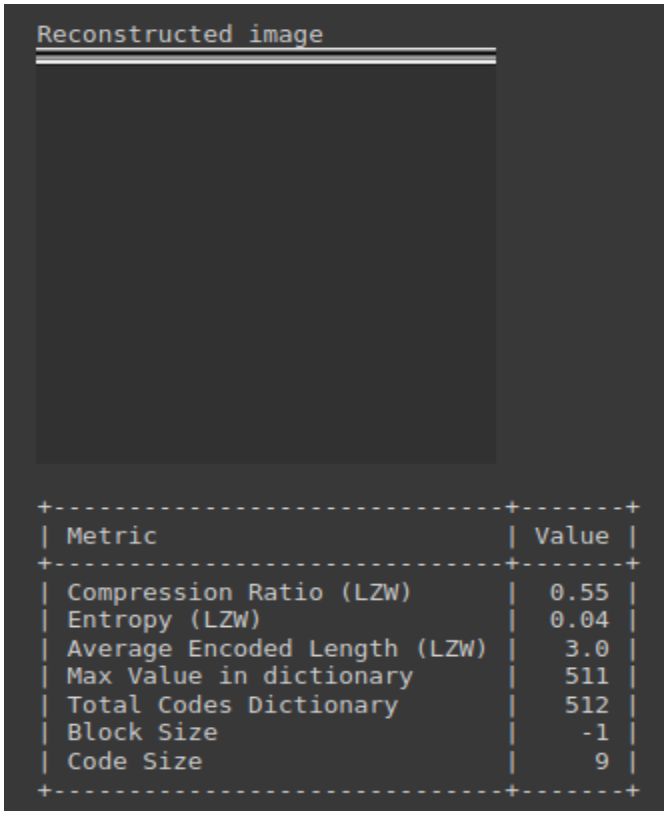
Reconstructed image



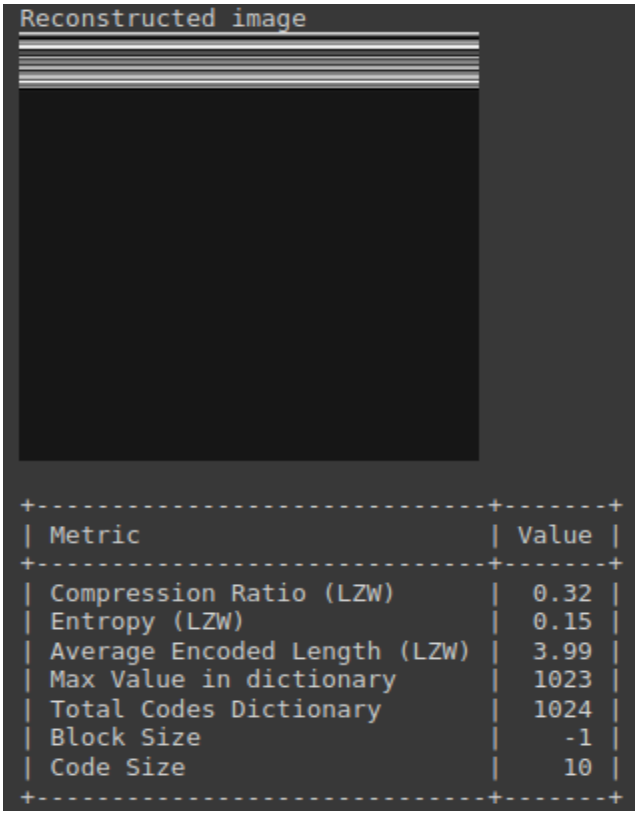
Metric	Value
Compression Ratio (LZW)	4.71
Entropy (LZW)	4.68
Average Encoded Length (LZW)	2.98
Max Value in dictionary	319
Total Codes Dictionary	74312
Block Size	16
Code Size	10

All the formed images are reconstructed images of the original images. I have changed the block size and given different dictionary sizes to show that the LZW compression is lossless. From the matrices we can observe that increasing the block size will increase the number of encoded data hence we need a larger dictionary to store encoded data of a particular block.

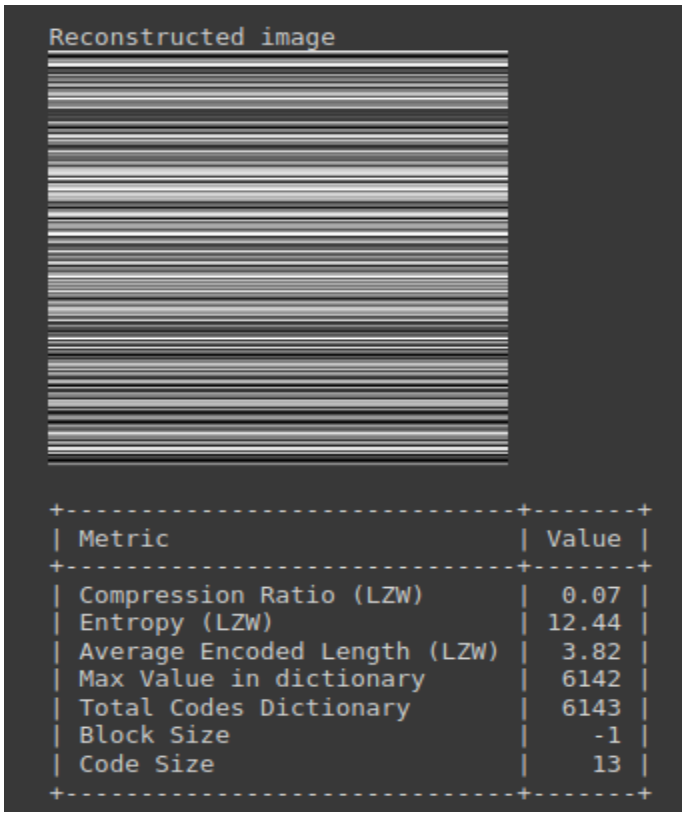
Image : Fig81b.tif



Metric	Value
Compression Ratio (LZW)	0.55
Entropy (LZW)	0.04
Average Encoded Length (LZW)	3.0
Max Value in dictionary	511
Total Codes Dictionary	512
Block Size	-1
Code Size	9



Metric	Value
Compression Ratio (LZW)	0.32
Entropy (LZW)	0.15
Average Encoded Length (LZW)	3.99
Max Value in dictionary	1023
Total Codes Dictionary	1024
Block Size	-1
Code Size	10

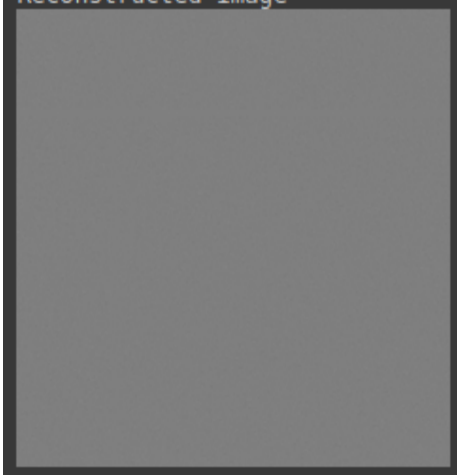


Metric	Value
Compression Ratio (LZW)	0.07
Entropy (LZW)	12.44
Average Encoded Length (LZW)	3.82
Max Value in dictionary	6142
Total Codes Dictionary	6143
Block Size	-1
Code Size	13

In these images I have used the block size as the image size and varied to code size to plot the reconstructed image. We can observe that when the block size is exactly equal to the image size then code size must so that the encoding done will be lossless. We can see in the figure 3 that for the code size 13 the image obtained is lossless.

Image : Fig81c.tif

Reconstructed image

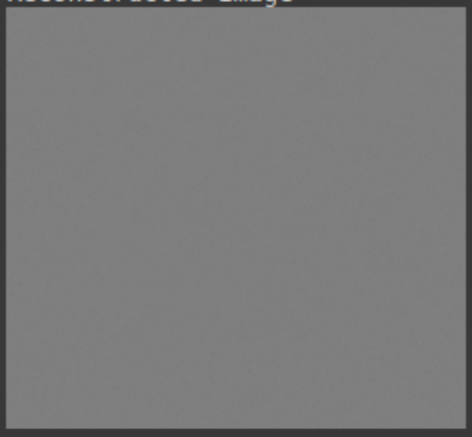


Metric	Value
Compression Ratio (LZW)	7.82
Entropy (LZW)	2.67
Average Encoded Length (LZW)	3.0
Max Value in dictionary	270
Total Codes Dictionary	1092735
Block Size	4
Code Size	9

Reconstructed image

Metric	Value
Compression Ratio (LZW)	7.82
Entropy (LZW)	3.95
Average Encoded Length (LZW)	3.0
Max Value in dictionary	297
Total Codes Dictionary	296778
Block Size	8
Code Size	9

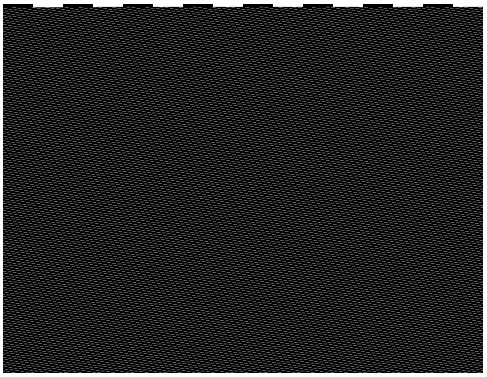
Reconstructed image



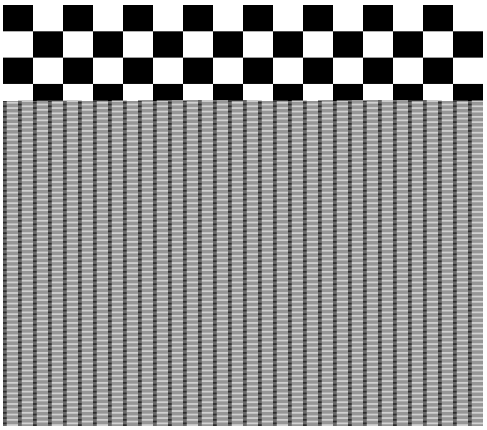
Metric	Value
Compression Ratio (LZW)	7.82
Entropy (LZW)	5.32
Average Encoded Length (LZW)	3.0
Max Value in dictionary	371
Total Codes Dictionary	92118
Block Size	16
Code Size	9

For the input image, using any block size makes no difference as we can generate the image each time with 0 RMSE.

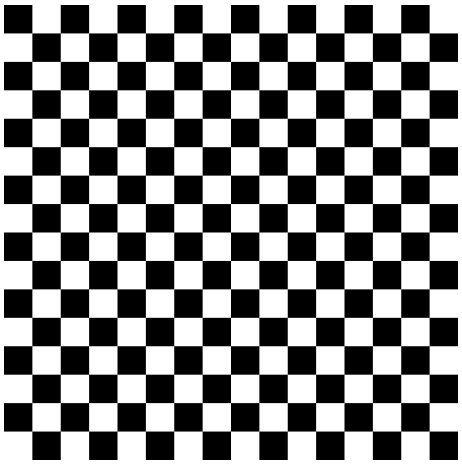
Image :Checkerboard.tif



Metric	Value
Compression Ratio (LZW)	1.15
Entropy (LZW)	0.0
Average Encoded Length (LZW)	3.0
Max Value in dictionary	511
Total Codes Dictionary	512
Block Size	-1
Code Size	9



Metric	Value
Compression Ratio (LZW)	4.31
Entropy (LZW)	0.07
Average Encoded Length (LZW)	4.0
Max Value in dictionary	4095
Total Codes Dictionary	4096
Block Size	-1
Code Size	12



Metric	Value
Compression Ratio (LZW)	59.28
Entropy (LZW)	13.58
Average Encoded Length (LZW)	4.14
Max Value in dictionary	12672
Total Codes Dictionary	12673
Block Size	-1
Code Size	15

This image clearly shows how important it is to have a dictionary whose size can incorporate entire image pixel values. It is clearly visible as the size of the dictionary is increased, the image is generated and at last generated completely.

Image :lena.tif

Metric	Value
Compression Ratio (LZW)	3.36
Entropy (LZW)	10.46
Average Encoded Length (LZW)	3.27
Max Value in dictionary	10916
Total Codes Dictionary	152995
Block Size	128
Code Size	15

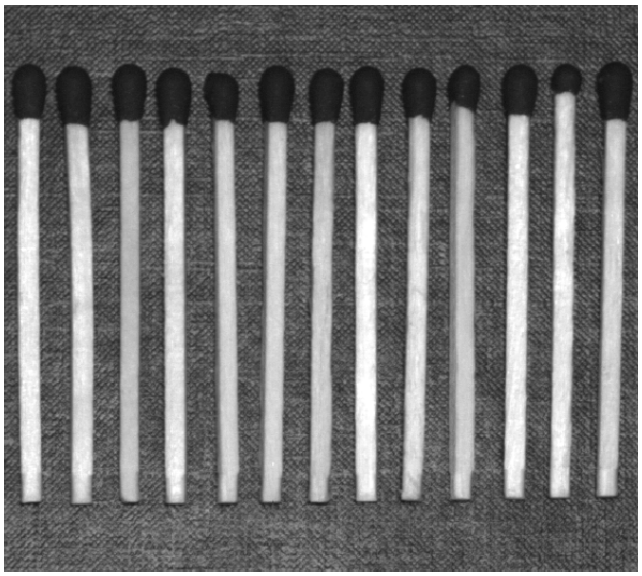
Metric	Value
Compression Ratio (LZW)	3.36
Entropy (LZW)	8.83
Average Encoded Length (LZW)	2.95
Max Value in dictionary	3562
Total Codes Dictionary	186128
Block Size	64
Code Size	19

Metric	Value
Compression Ratio (LZW)	3.36
Entropy (LZW)	5.91
Average Encoded Length (LZW)	2.65
Max Value in dictionary	511
Total Codes Dictionary	475819
Block Size	16
Code Size	9

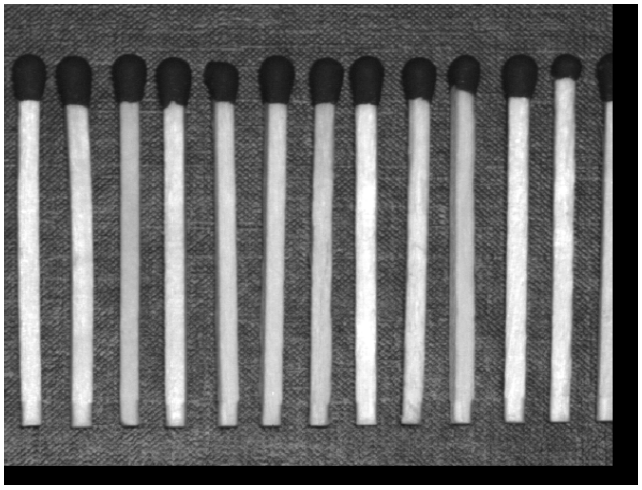
Metric	Value
Compression Ratio (LZW)	3.36
Entropy (LZW)	3.27
Average Encoded Length (LZW)	2.59
Max Value in dictionary	271
Total Codes Dictionary	4442054
Block Size	4
Code Size	19

For the mentioned block size and code size, the reconstructed image is shown above. The reconstructed image formed is lossless for these sets of values. We can clearly observe that the maximum value present in the dictionary depends on the code size.(Directly proportional)

Image :matches-aligned.tif



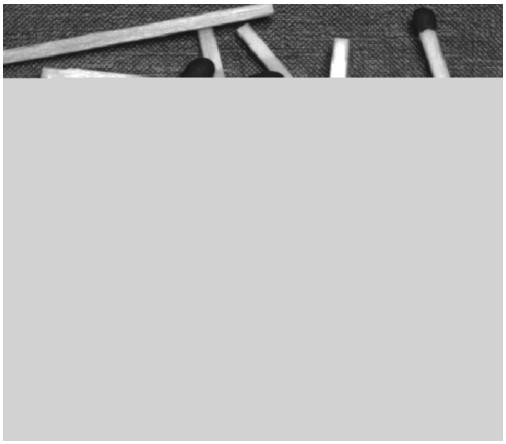
Metric	Value
Compression Ratio (LZW)	2.2
Entropy (LZW)	5.02
Average Encoded Length (LZW)	2.44
Max Value in dictionary	319
Total Codes Dictionary	1775418
Block Size	8
Code Size	9



Metric	Value
Compression Ratio (LZW)	2.4
Entropy (LZW)	7.34
Average Encoded Length (LZW)	2.52
Max Value in dictionary	1166
Total Codes Dictionary	360241
Block Size	32
Code Size	19

When the block size is 8 there is no padding since the image can be perfectly divided into a set of blocks of 8, therefore the formed image has no zero padded values. In cases when the image size is not divisible, zeros are padded to reconstruct the image. In the second case when the block size is 32 and the code size is 19, their is noise in the image due to smaller code size.

Image : Matches-random.tif



Metric	Value
Compression Ratio (LZW)	10.65
Entropy (LZW)	1.02
Average Encoded Length (LZW)	3.98
Max Value in dictionary	32767
Total Codes Dictionary	32768
Block Size	-1
Code Size	15

Metric	Value
Compression Ratio (LZW)	3.86
Entropy (LZW)	4.44
Average Encoded Length (LZW)	4.7
Max Value in dictionary	65535
Total Codes Dictionary	65536
Block Size	-1
Code Size	16

Metric	Value
Compression Ratio (LZW)	2.05
Entropy (LZW)	14.12
Average Encoded Length (LZW)	4.28
Max Value in dictionary	162841
Total Codes Dictionary	162842
Block Size	-1
Code Size	18

The size of the dictionary mattered a lot in this image reconstruction as well. Exponential increase in the dictionary size made it feasible for the image to be generated nicely in the end.

Image : fingerprint.tif

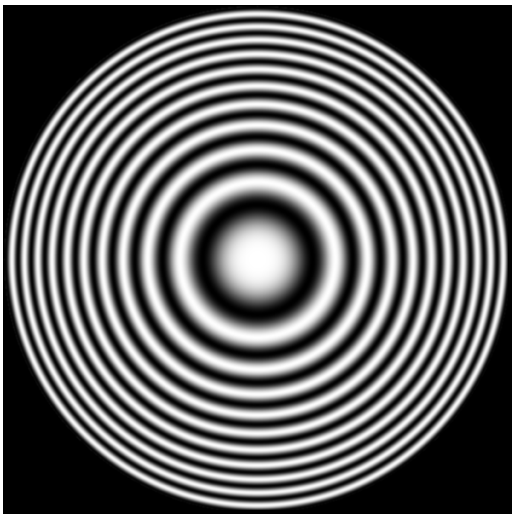
Metric	Value
Compression Ratio (LZW)	2.76
Entropy (LZW)	108.06
Average Encoded Length (LZW)	33.99
Max Value in dictionary	23953
Total Codes Dictionary	202372
Block Size	256
Code Size	2000

Metric	Value
Compression Ratio (LZW)	2.37
Entropy (LZW)	438.13
Average Encoded Length (LZW)	140.97
Max Value in dictionary	7409
Total Codes Dictionary	286662
Block Size	128
Code Size	100

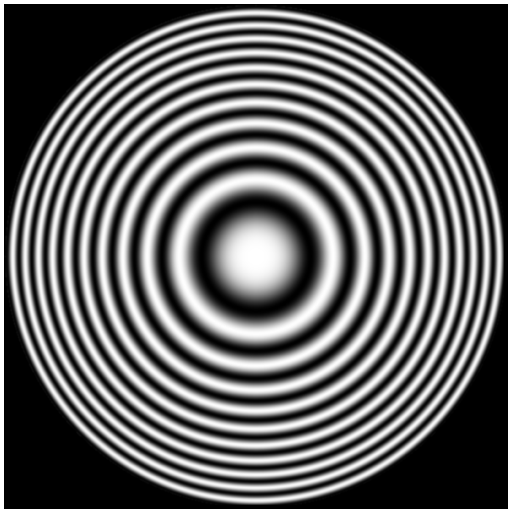
Metric	Value
Compression Ratio (LZW)	2.17
Entropy (LZW)	143189.21
Average Encoded Length (LZW)	129538.61
Max Value in dictionary	268
Total Codes Dictionary	12767755
Block Size	4
Code Size	200

The image size in this case was a bit different than the others and needed padding as can be seen from the above image samples. I had to pad the images with 0 that is the reason the black patches are visible along the ends of rows and columns. The size of dictionary mattered a lot as already mentioned in previous observations as well.

Image : zoneplate.tif



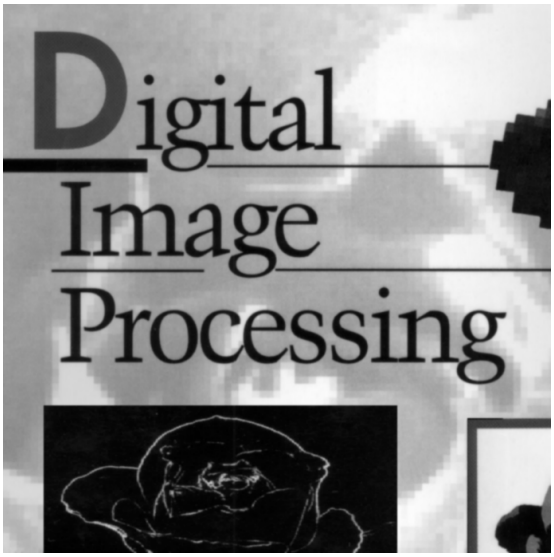
Metric	Value
Compression Ratio (LZW)	3.68
Entropy (LZW)	9096.6
Average Encoded Length (LZW)	3578.39
Max Value in dictionary	507
Total Codes Dictionary	603073
Block Size	16
Code Size	100



Metric	Value
Compression Ratio (LZW)	3.68
Entropy (LZW)	9096.6
Average Encoded Length (LZW)	3578.39
Max Value in dictionary	507
Total Codes Dictionary	603073
Block Size	16
Code Size	9

Even when the code size has such a massive difference, the image generation had no issues whatsoever and the reconstruction was perfect.

Image :bookcover.tif



Metric	Value
Compression Ratio (LZW)	4.42
Entropy (LZW)	88917.87
Average Encoded Length (LZW)	79433.89
Max Value in dictionary	271
Total Codes Dictionary	7942532
Block Size	4
Code Size	9

Metric	Value
Compression Ratio (LZW)	4.42
Entropy (LZW)	33287.36
Average Encoded Length (LZW)	20247.06
Max Value in dictionary	319
Total Codes Dictionary	2221791
Block Size	8
Code Size	9

Metric	Value
Compression Ratio (LZW)	4.42
Entropy (LZW)	11194.62
Average Encoded Length (LZW)	5155.4
Max Value in dictionary	502
Total Codes Dictionary	760388
Block Size	16
Code Size	9

For this image i have kept the code size to be constant i.e 9 and observed that the image reconstructed is same as that of the original image.
But this case is not true for any block size, as number of encodings in a dictionary can be only 512 so we need a block size such that there are maximum 512 encodings possible(in case of code size = 9). Distortions might come for block size greater than 16.