EE669 HW4 Report

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Part A

(1)Read image

(2)Subtract value

(3)DCT coefficients

format:[[block1],[block2],...]

```
[[[-2.65000000e+02 -3.15521889e+01  8.08417892e+01  1.89980233e+00
    2.85000000e+01 -8.25676880e+01 -7.13694916e+01 -4.02203484e+01]
  [ 6.28598633e+01 -3.26879349e+01  6.16217728e+01  1.90632763e+01
   -2.32404780e+00  3.49092255e+01  1.89670753e+01  3.73932648e+00]
  [-3.97624664e+01  9.46196442e+01 -2.69564762e+01  2.72449265e+01
    1.77806988e+01 -8.73588848e+00  1.25977182e+01  8.67107010e+00]
  [ 1.68175678e+01  2.03150539e+01 -3.59234276e+01  4.65701141e+01
   -2.09032803e+01  1.79544926e+01 -1.39042139e+01  3.85712314e+00]
  [-1.25000000e+00 -1.59312611e+01  2.39376278e+01 -3.26734428e+01
    4.25000000e+00 -2.49692869e+00  2.26162171e+00 -7.32505512e+00]
  [-1.96823673e+01  1.72221966e+01 -3.05049915e+01  1.73635025e+01
   -9.85020161e+00 -8.34865856e+00  4.52713907e-01  2.62177253e+00]
  [ 5.91682863e+00 -1.23192883e+01  6.84771824e+00 -1.37730684e+01
    3.72951365e+00 -1.96550572e+00 -7.93524563e-01 -4.30213499e+00]
  [-1.81285155e+00  1.14833617e+00  6.42178059e-01  7.84057021e-01
   -1.65836120e+00 -5.16044199e-01  1.24051414e-01  1.96647942e+00]]

 [[-1.10250000e+02  1.45781479e+02  3.12794209e+01 -2.76943626e+01
   -3.00000000e+00 -2.18707848e+01 -4.83841896e+00  5.59682703e+00]
  [-5.95281181e+01  2.29162502e+01 -1.35197510e+02  1.10052711e+02
    7.85368805e+01 -6.94665766e+00  3.11492405e+01 -4.48246002e+00]
  [-5.57542648e+01 -9.96723633e+01 -1.53566017e+01  5.55955200e+01
   -1.09474579e+02  4.40341339e+01  3.66421356e+01 -3.91121330e+01]
  [ 6.68147659e+01 -4.30542488e+01 -7.14863968e+01 -8.77498856e+01
    6.04244089e+00  3.37830048e+01 -4.51052666e+01  1.65467224e+01]
  [ 4.20000000e+01  9.88396549e+00  1.91608849e+01 -3.25656056e+00
    3.27500000e+01 -5.21004219e+01 -1.25368652e+01  3.28195534e+01]
  [-2.08547878e+01  1.35071020e+01  7.04273834e+01 -5.94491768e+00
   -4.00075293e+00 -2.64607925e+01 -2.31319523e+00 -3.08368564e+00]
  [-7.21280956e+00  2.01399422e+00 -8.35786438e+00 -1.56516562e+01
    1.53094702e+01  1.27964706e+01  5.85660172e+00  7.50095654e+00]
  [ 1.59026213e+01  9.78961754e+00 -2.91273546e+00  1.29760942e+01
    2.57500706e+01  9.99888611e+00 -6.82544708e-01  4.29442835e+00]]
```

```
[[-4.55875000e+02  7.37346954e+01  8.70035324e+01 -3.37402878e+01
  -1.66250000e+01 -1.41094193e+02 -7.05392914e+01 -4.61820107e+01]
 [ 2.68621960e+01 -2.93667831e+01 -3.42498665e+01 -5.18948936e+01
  -1.15122452e+01  1.70165081e+01  5.12521937e-02 -9.87647057e+00]
 [ 2.34272709e+01 -2.46419621e+01  6.62905502e+01 -3.05469742e+01
   5.65337133e+00  4.14967537e+01 -1.41720190e+01 -3.82943535e+00]
 [-3.99374986e+00  7.70912743e+00  3.91323948e+00  5.18017435e+00
   8.23866558e+00  3.21981692e+00  2.57157350e+00  9.02701974e-01]
 [ 2.37500000e+00  1.21169434e+01 -1.50755424e+01 -9.79330635e+00
   2.41250000e+01 -2.76718348e-01 -2.36565895e+01  1.06069212e+01]
 [-1.83764327e+00  2.18955088e+00 -4.83201265e+00 -4.65886259e+00
   1.23580952e+01 -1.75913391e+01 -8.66544127e-01  1.67574894e+00]
 [ 1.18086519e+01 -1.66481566e+00  2.32798076e+00  1.28609581e+01
   4.82914543e+00 -4.46008778e+00  1.09594469e+01 -1.11721811e+01]
 [-2.24341607e+00  2.24484944e+00  1.42744467e-01 -1.48312962e+00
   3.88041019e+00 -2.48714757e+00  4.41849327e+00 -7.22051620e-01]]

[[-1.05125000e+02 -4.88859634e+01  6.53516998e+01  1.49137239e+01
  -7.28750000e+01 -1.73198528e+01 -7.18060541e+00  4.99535894e+00]
 [ 3.21732807e+00 -1.49034302e+02  1.56113907e+02  4.49586868e+01
   2.51978111e+01 -7.13746033e+01 -3.04374542e+01  1.63039532e+01]
 [-3.88037643e+01  8.30408401e+01 -4.13089523e+01 -4.79763069e+01
   1.20326817e+00  1.53733110e+01  6.40656815e+01 -4.88587570e+01]
 [-2.37194586e+00  5.59386330e+01 -4.29088326e+01  1.16917791e+01
  -8.37821503e+01  9.58034706e+00  1.88354416e+01  9.16585636e+00]
 [-5.06250000e+01 -1.14513359e+01  1.08202810e+01  1.36977186e+01
   1.46250000e+01  1.13106499e+01 -4.73716965e+01 -9.46023846e+00]
 [-3.86831284e+00 -4.10090027e+01 -6.10276842e+00  7.11067677e+00
   1.00717287e+01 -9.04828966e-01  8.75765610e+00 -2.52611160e+01]
 [ 2.67844224e+00  1.35740304e+00 -1.36843204e+01 -6.48913240e+00
  -9.83404255e+00 -7.05295277e+00 -7.19104910e+00  7.75597954e+00]
 [-1.67964668e+01  1.98342838e+01 -1.74368119e+00  7.43488446e-02
  -1.93776913e+01  1.80183256e+00 -1.31515141e+01 -1.75264382e+00]]]
```

(4)Quantized matrix for all four DCT coefficient blocks

```
[array([[-17,  -3,   8,   0,   1,  -2,  -1,  -1],
       [  5,  -3,   4,   1,   0,   1,   0,   0],
       [ -3,   7,  -2,   1,   0,   0,   0,   0],
       [  1,   1,  -2,   2,   0,   0,   0,   0],
       [  0,  -1,   1,  -1,   0,   0,   0,   0],
       [ -1,   0,  -1,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0]]),
```

```
array([[ -7,  13,   3,  -2,   0,  -1,   0,   0],
       [ -5,   2, -10,   6,   3,   0,   1,   0],
       [ -4,  -8,  -1,   2,  -3,   1,   1,  -1],
       [  5,  -3,  -3,  -3,   0,   0,  -1,   0],
       [  2,   0,   1,   0,   0,   0,   0,   0],
       [ -1,   0,   1,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0]]),
array([[-28,   7,   9,  -2,  -1,  -4,  -1,  -1],
       [  2,  -2,  -2,  -3,   0,   0,   0,   0],
       [  2,  -2,   4,  -1,   0,   1,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   1,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0]]),
array([[ -7,  -4,   7,   1,  -3,   0,   0,   0],
       [  0, -12,  11,   2,   1,  -1,  -1,   0],
       [ -3,   6,  -3,  -2,   0,   0,   1,  -1],
       [  0,   3,  -2,   0,  -2,   0,   0,   0],
       [ -3,  -1,   0,   0,   0,   0,   0,   0],
       [  0,  -1,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0]])]
```

Discussion:

Human eyes are more sensitive to low frequency-details. Quantization matrix has larger value for high frequency coefficients than for low frequency coefficients. High frequency coefficients will be quantized heavily. This loss of information is acceptable since human eyes can't tell the difference.

Most of the image’s information is concentrated in low-frequency coefficients due to DCT’s energy compaction property. Thus, quantizing high-frequency coefficients would not lead to significant loss.

(5)quantization matrices Q_{10} and Q_{80}

Q80:

```
[[ 6.4  4.4  4.   6.4  9.6 16.  20.4 24.4]
 [ 4.8  4.8  5.6  7.6 10.4 23.2 24.  22. ]
 [ 5.6  5.2  6.4  9.6 16.  22.8 27.6 22.4]
 [ 5.6  6.8  8.8 11.6 20.4 34.8 32.  24.8]
 [ 7.2  8.8 14.8 22.4 27.2 43.6 41.2 30.8]
 [ 9.6 14.  22.  25.6 32.4 41.6 45.2 36.8]
 [19.6 25.6 31.2 34.8 41.2 48.4 48.  40.4]
 [28.8 36.8 38.  39.2 44.8 40.  41.2 39.6]]
```

Q10:

```
[[ 80.  55.  50.  80. 120. 200. 255. 305.]
 [ 60.  60.  70.  95. 130. 290. 300. 275.]
 [ 70.  65.  80. 120. 200. 285. 345. 280.]
 [ 70.  85. 110. 145. 255. 435. 400. 310.]
 [ 90. 110. 185. 280. 340. 545. 515. 385.]
 [120. 175. 275. 320. 405. 520. 565. 460.]
 [245. 320. 390. 435. 515. 605. 600. 505.]
 [360. 460. 475. 490. 560. 500. 515. 495.]]
```

	quantized matrices		
Quality factors	10	50	80
Block1	[[-3 -1 2 0 0 0 0 0] [1 -1 1 0 0 0 0 0] [-1 1 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-17 -3 8 0 1 -2 -1 -1] [5 -3 4 1 0 1 0 0] [-3 7 -2 1 0 0 0 0] [1 1 -2 2 0 0 0 0] [0 -1 1 -1 0 0 0 0] [-1 0 -1 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-41 -7 20 0 3 -5 -3 -2] [13 -7 11 3 0 2 1 0] [-7 18 -4 3 1 0 0 0] [3 3 -4 4 -1 1 0 0] [0 -2 2 -1 0 0 0 0] [-2 1 -1 1 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]
Block2	[[-1 3 1 0 0 0 0 0] [-1 0 -2 1 1 0 0 0] [-1 -2 0 0 -1 0 0 0] [1 -1 -1 -1 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-7 13 3 -2 0 -1 0 0] [-5 2 -10 6 3 0 1 0] [-4 -8 -1 2 -3 1 1 -1] [5 -3 -3 -3 0 0 -1 0] [2 0 1 0 0 0 0 0] [-1 0 1 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-17 33 8 -4 0 -1 0 0] [-12 5 -24 14 8 0 1 0] [-10 -19 -2 6 -7 2 1 -2] [12 -6 -8 -8 0 1 -1 1] [6 1 1 0 1 -1 0 1] [-2 1 3 0 0 -1 0 0] [0 0 0 0 0 0 0 0] [1 0 0 0 1 0 0 0]]
Block3	[[-6 1 2 0 0 -1 0 0] [0 0 0 -1 0 0 0 0] [0 0 1 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-28 7 9 -2 -1 -4 -1 -1] [2 -2 -2 -3 0 0 0 0] [2 -2 4 -1 0 1 0 0] [0 0 0 0 0 0 0 0] [0 1 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-71 17 22 -5 -2 -9 -3 -2] [6 -6 -6 -7 -1 1 0 0] [4 -5 10 -3 0 2 -1 0] [-1 1 0 0 0 0 0 0] [0 1 -1 0 1 0 -1 0] [0 0 0 0 0 0 0 0] [1 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]
Block4	[[-1 -1 1 0 -1 0 0 0] [0 -2 2 0 0 0 0 0] [-1 1 -1 0 0 0 0 0] [0 1 0 0 0 0 0 0] [-1 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-7 -4 7 1 -3 0 0 0] [0 -12 11 2 1 -1 -1 0] [-3 6 -3 -2 0 0 1 -1] [0 3 -2 0 -2 0 0 0] [-3 -1 0 0 0 0 0 0] [0 -1 0 0 0 0 0 0] [0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0]]	[[-16 -11 16 2 -8 -1 0 0] [1 -31 28 6 2 -3 -1 1] [-7 16 -6 -5 0 1 2 -2] [0 8 -5 1 -4 0 1 0] [-7 -1 1 1 1 0 -1 0] [0 -3 0 0 0 0 0 -1] [0 0 0 0 0 0 0 0] [-1 1 0 0 0 0 0 0]]

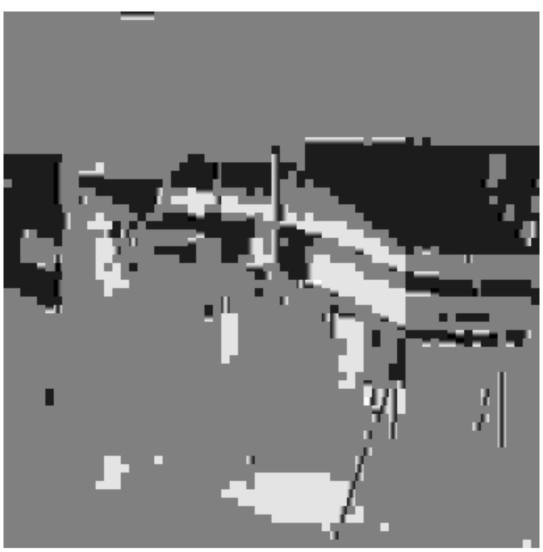
Discussion: There are many zeros in the quality factor 10 matrix, which is very suitable for entropy coding. However, the image quality is degraded dramatically. The quality factor 50 matrix provided a good balance between the bits saving and image quality. For the quality factor 80, there are less zeros, which is not very suitable for entropy coding. Thus, quality factor 50 matrix is the most suitable one.

Part B

(a)

quality factors	compressed file sizes(kb)	compression ratios	PSNR
100	188	0.7148288973	58.49333017
90	79	0.3003802281	39.10901895
50	28	0.1064638783	33.97533281
20	16	0.0608365019	32.27276335
10	10	0.03802281369	31.13985989
1	4	0.01520912548	28.03503039

(b)

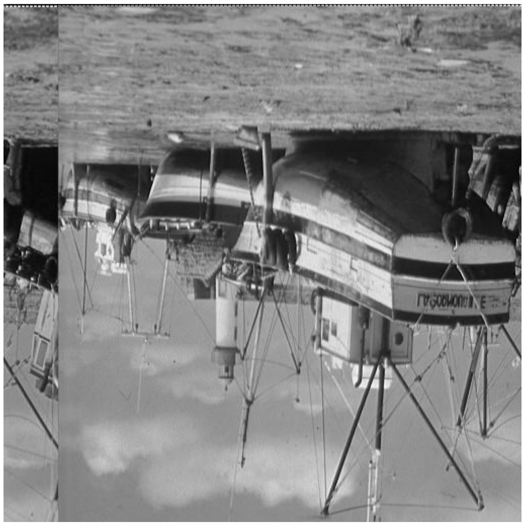


Quality factor:1

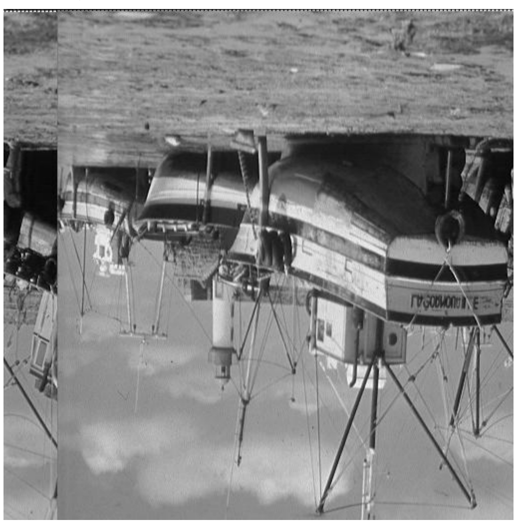
Quality factor:10

Quality factor:20

Quality factor:50



Quality factor:90



Quality factor:100

The smaller the quality factor, the lower the image quality. Small quantization matrix will zeros out most of the DCT coefficients.

In Quality factor:1, we can see some of the brightness is loss. This result is reasonable as the DC coefficient was divided by a large scaler from the quantization matrix with quality factor 10.

In Quality factor:10, we can see some blocking and banding. These come from the nature of block-based transform coding schemes and quantization.

In Quality factor:20, we can still see blocking and banding. But there are much lighter than those in Quality factor:10.

In Quality factor:50, we can see ringing. This artifact is contributed by the absence of high-frequency coefficients. We zero out most of the high-frequency coefficients.

I can barely find flaws in Quality factor:90 and 100.

Part C

(a)PSNR w.r.t the original images without compression.

PSNR	Images
32.73870329277156	camera_man1
34.383214456472494	camera_man2
127.31742544327544	pepper_1
128.8235525466598	pepper_2

(b)
(1)Reducing the blocking effect.

PSNR	Images
27.99534996204911	camera_man1
28.10835617016789	camera_man2
125.76596098998385	pepper_1
126.26646693394935	pepper_2

(2)

1.odd symmetric extension PSNR	2.replication PSNR	3.zero- shift replacement. PSNR	Images
31.312675234592646	31.57048110109624	31.2173881404367	camera_man1
31.37394776447986	31.656189507602384	31.317683052572967	camera_man2
124.10696000410276	124.10522057792691	124.1134459141992	pepper_1
124.0994370637518	124.10301149508307	124.1124873193236	pepper_2

1_camer_man1

2_camera_man1

3_camera_man1

1_camera_man2

2_camera_man2

3_camera_man2

(3)

The PSNR of post-processed images is lower than that of original images. There is a inconsistency between objective quality and subjective quality. In the view of PSNR, images in (2) have higher PSNR value, which is closer original images. However, from my observations, images in (1) have higher quality. Although images in (a) have blocking effects, they are clearer than images in (2). Averaging the block boundary indeed improves the PSNR, but it leads to blurring. Human eyes are more sensitive to blurring.