Problem1

a

- n=5
  - ```
    d= [0.00000, 0.79925, 1.54979, 2.30071, 3.18268, 4.00000]
    r= [0.43750, 1.16100, 1.93857, 2.66286, 3.70250]
    ```
- n=6
  - ```
    d= [0.00000, 0.78208, 1.44333, 2.09667, 2.63667, 3.27125, 4.00000]
    r= [0.43750, 1.12667, 1.76000, 2.43333, 2.84000, 3.70250]
    ```
- n= 8
  - ```
    d= [0.00000, 0.38083, 1.00869, 1.53686, 2.08525, 2.51500, 2.93625, 3.50083,
    4.00000]
    r = [0.00000, 0.76167, 1.25571, 1.81800, 2.35250, 2.67750, 3.19500, 3.80667]
    ```

b

- n=5
  - Q = [0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4]
  - $\hat{X}$ = [0.43750, 0.43750, 0.43750, 0.43750, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 3.70250, 3.70250, 3.70250, 3.70250]
  - MSE = 0.04650
- n=6
  - Q = [0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 5, 5, 5, 5]
  - $\hat{X}$ = [0.43750, 0.43750, 0.43750, 0.43750, 1.12667, 1.12667, 1.12667, 1.12667, 1.12667, 1.12667, 1.12667, 1.12667, 1.12667, 1.76000, 1.76000, 1.76000, 1.76000, 1.76000, 1.76000, 2.43333, 2.43333, 2.43333, 2.43333, 2.43333, 2.43333, 2.84000, 2.84000, 2.84000, 3.70250, 3.70250, 3.70250, 3.70250]
  - MSE = 0.03674
- n=8
  - Q = [0, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 6, 6, 7, 7, 7]
  - $\hat{X}$ = [0.00000, 0.76167, 0.76167, 0.76167, 0.76167, 0.76167, 0.76167, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.81800, 1.81800, 1.81800, 1.81800, 1.81800, 2.35250, 2.35250, 2.35250, 2.35250, 2.67750, 2.67750, 2.67750, 2.67750, 3.19500, 3.19500, 3.80667, 3.80667, 3.80667]
  - MSE = 0.02386

c

- n=5
  - Q = [0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4]
  - $\hat{X}$ = [0.40, 0.40, 0.40, 0.40, 1.20, 1.20, 1.20, 1.20, 1.20, 1.20, 1.20, 1.20, 1.20, 1.20, 2.00, 2.00, 2.00, 2.00, 2.00, 2.00, 2.00, 2.80, 2.80, 2.80, 2.80, 2.80, 2.80, 2.80, 3.60, 3.60, 3.60, 3.60]
  - MSE = 0.05340
- n=6
    ```

- Q = [0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 4, 4, 4, 5, 5, 5, 5]
- $\hat{X}$ = [0.33, 0.33, 0.33, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.67, 1.67, 1.67, 1.67, 1.67, 1.67, 1.67, 1.67, 2.33, 2.33, 2.33, 2.33, 2.33, 2.33, 3.00, 3.00, 3.00, 3.67, 3.67, 3.67, 3.67]
- MSE = 0.04465

- n=8
  - Q = [0, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 6, 6, 7, 7, 7]
  - $\hat{X}$ = [0.25, 0.75, 0.75, 0.75, 0.75, 0.75, 0.75, 1.25, 1.25, 1.25, 1.25, 1.25, 1.25, 1.25, 1.75, 1.75, 1.75, 1.75, 1.75, 2.25, 2.25, 2.25, 2.25, 2.75, 2.75, 2.75, 2.75, 3.25, 3.25, 3.75, 3.75, 3.75]
  - MSE = 0.02903

d

- n=5
  - Q = [0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4]
  - $\hat{X}$ = [0.43750, 0.43750, 0.43750, 0.43750, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.16100, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 1.93857, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 2.66286, 3.70250, 3.70250, 3.70250, 3.70250]
  - MSE = 0.04650
- n=6
  - Q = [0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 4, 4, 4, 5, 5, 5, 5]
  - $\hat{X}$ = [0.35667, 0.35667, 0.35667, 1.00875, 1.00875, 1.00875, 1.00875, 1.00875, 1.00875, 1.00875, 1.00875, 1.66375, 1.66375, 1.66375, 1.66375, 1.66375, 1.66375, 1.66375, 1.66375, 2.43333, 2.43333, 2.43333, 2.43333, 2.43333, 2.43333, 2.84000, 2.84000, 2.84000, 3.70250, 3.70250, 3.70250, 3.70250]
  - MSE = 0.04014
- n=8
  - Q = [0, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 6, 6, 7, 7, 7]
  - $\hat{X}$ = [0.00000, 0.76167, 0.76167, 0.76167, 0.76167, 0.76167, 0.76167, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.25571, 1.81800, 1.81800, 1.81800, 1.81800, 1.81800, 2.35250, 2.35250, 2.35250, 2.35250, 2.67750, 2.67750, 2.67750, 2.67750, 3.19500, 3.19500, 3.80667, 3.80667, 3.80667]
  - MSE = 0.02386

e

n	5	6	8
ML_n	0.04650	0.03674	0.02386
UQ_n	0.05340	0.04465	0.02903
SUQ_n	0.04650	0.04014	0.02386

Max-Lloyd quantizer has the best MSE among these quantizers

Problem2

a

entropy(G) = 6.5977

b

- entropy(G'_u) = 0.6916
- dispaly $\hat{G}'_u$
  - 

- $SNR(G, \hat{G}_u)$ = 21.6257

c

- entropy(G'_{su}) = 0.6916
- display $\hat{G}'_{su}$

- $SNR(G, \hat{G'_{su}})$ = 21.7712

d

- entropy(G'_{op}) = 0.6735
- display $\hat{G_{op}}$

- $SNR(G, \hat{G_{op}})$ = 21.9496

e

- $SNR(G, \hat{G_{u}})$ = 21.6257
- $SNR(G, \hat{G_{su}'})$ = 21.7712
- $SNR(G, \hat{G_{op}})$ = 21.9496
- In these three quantizers, the max-lloyd quantizer has the best SNR, and the uniform quantizer has the worst snr.

Problem 3

a

- n = 5
  - r = [2.6629,1.9386,0.4375,3.7025,1.1610]
- n = 6
  - r = [0.4375,0.9780,1.3867,1.9380,2.6150,3.7025]
- n = 8
  - r= [0,0.8300,1.4314,2.0540,2.5580,2.9250,3.4800,3.9250]

X	n=5	n=6	n=8
0	0.4375	0.6529	0
0.52	0.4375	0.6529	0.83
0.55	0.4375	0.6529	0.83
0.68	0.4375	0.6529	0.83
0.91	1.161	0.6529	0.83
0.94	1.161	0.6529	0.83
0.97	1.161	0.6529	0.83
1.03	1.161	1.2988	0.83
1.04	1.161	1.2988	0.83
1.2	1.161	1.2988	1.4314
1.3	1.161	1.2988	1.4314
1.35	1.161	1.2988	1.4314
1.4	1.161	1.2988	1.4314
1.47	1.161	1.2988	1.4314
1.6	1.9386	1.2988	1.4314
1.7	1.9386	1.995	1.4314
1.85	1.9386	1.995	2.054
1.95	1.9386	1.995	2.054
1.99	1.9386	1.995	2.054
2.2	1.9386	1.995	2.054
2.28	1.9386	1.995	2.054
2.45	2.6629	2.6629	2.558
2.48	2.6629	2.6629	2.558
2.56	2.6629	2.6629	2.558
2.63	2.6629	2.6629	2.558
2.67	2.6629	2.6629	2.558
2.85	2.6629	2.6629	2.925
3	2.6629	2.6629	2.925
3.39	3.7025	3.48	3.48
3.57	3.7025	3.48	3.48

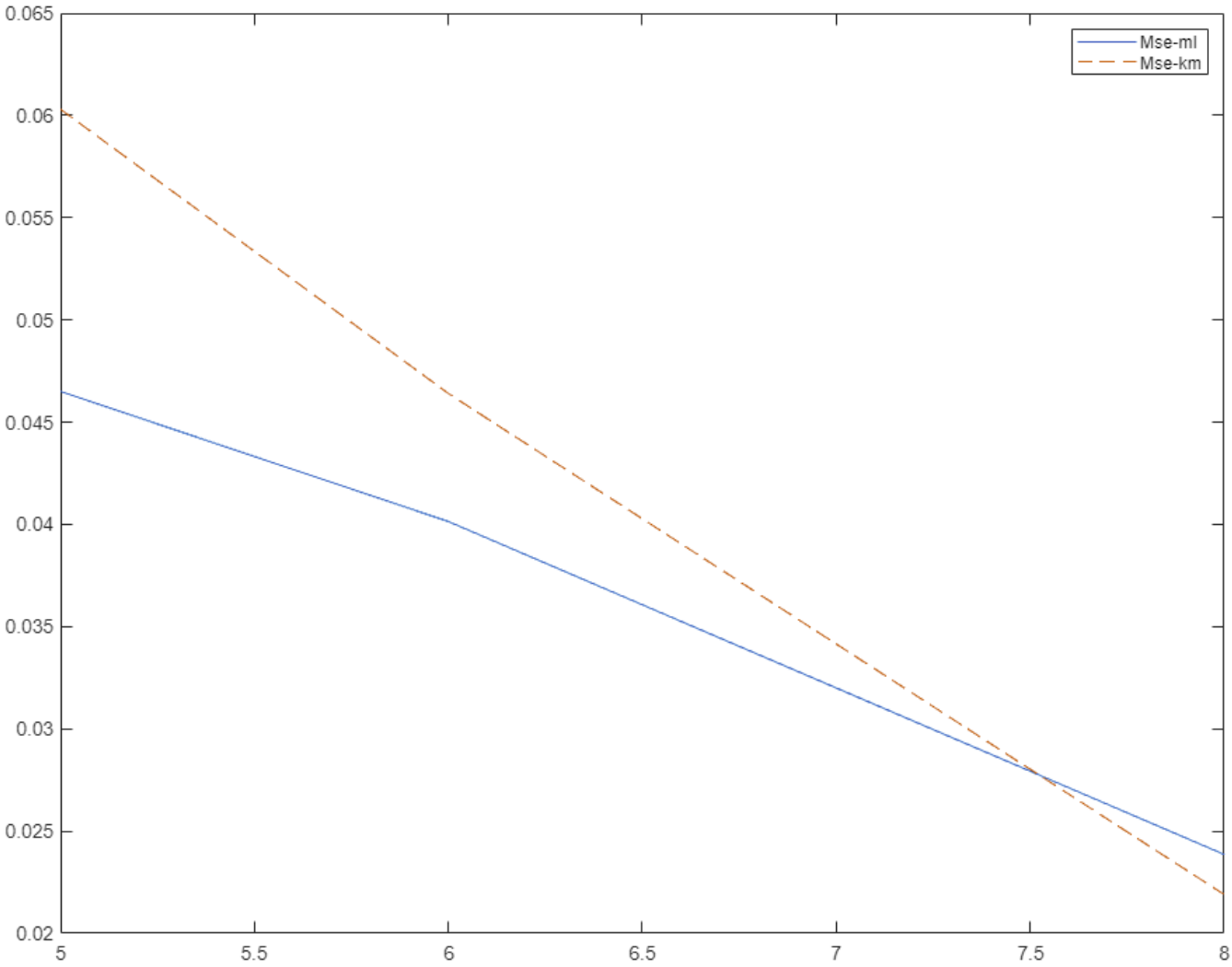
X	n=5	n=6	n=8
3.86	3.7025	3.925	3.925
3.99	3.7025	3.925	3.925

b

MSE

- n=5
  - mse = 0.0603
- n=6
  - mse = 0.0464
- n=8
  - mse = 0.0219

c



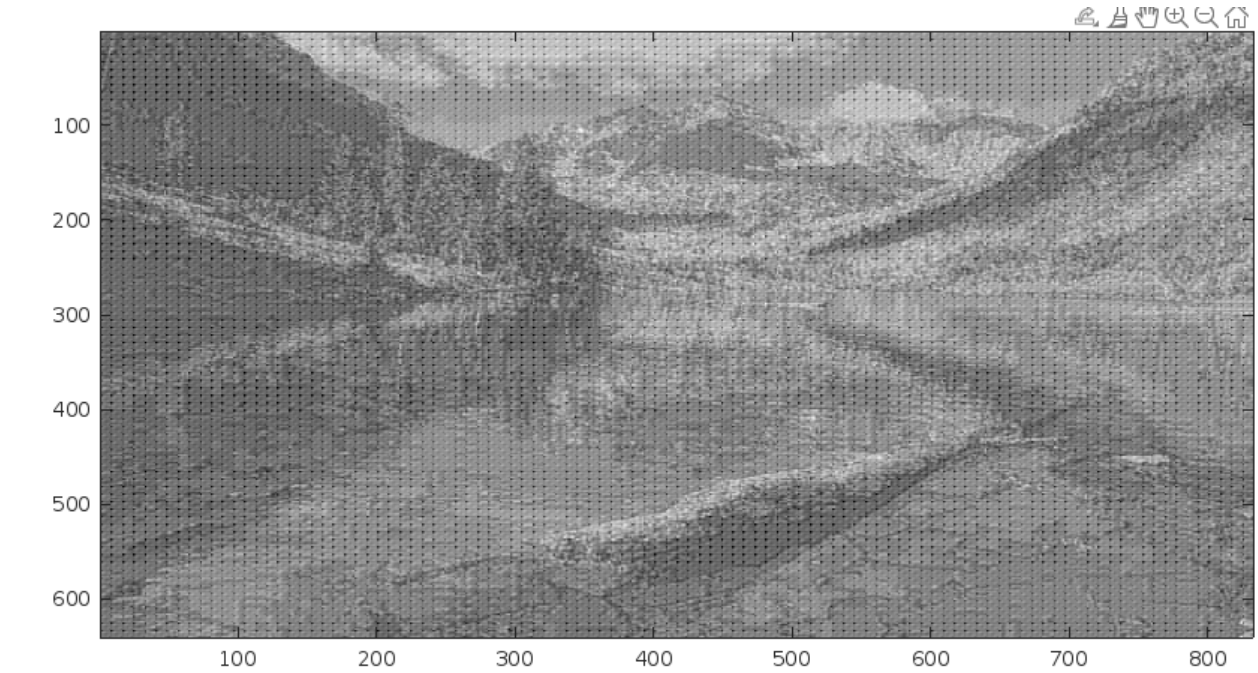
- ml for Max-Lloyd
- km for K-means

Problem 4

a

- Compute the resulting bitrate
  - For a 640*832 image, the bit needed to store is $(3 * 1 + 2 * 14) * 80 * 104 = 257920$
  - bitrate = $\frac{257920}{640*832} = 0.4843$
- and the compression ratio
  - bit needed before is $8 * 640 * 832 = 4259840$
  - compression ratio is 16.51

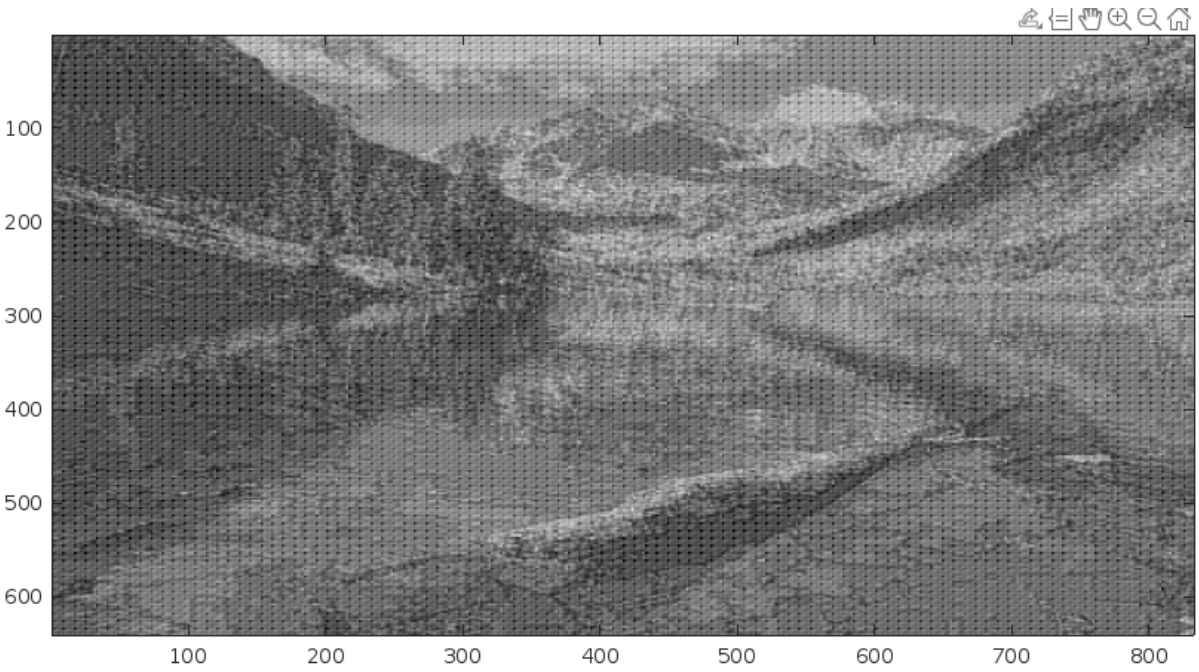
b

- Display image
  - 

- SNR = 7.6859

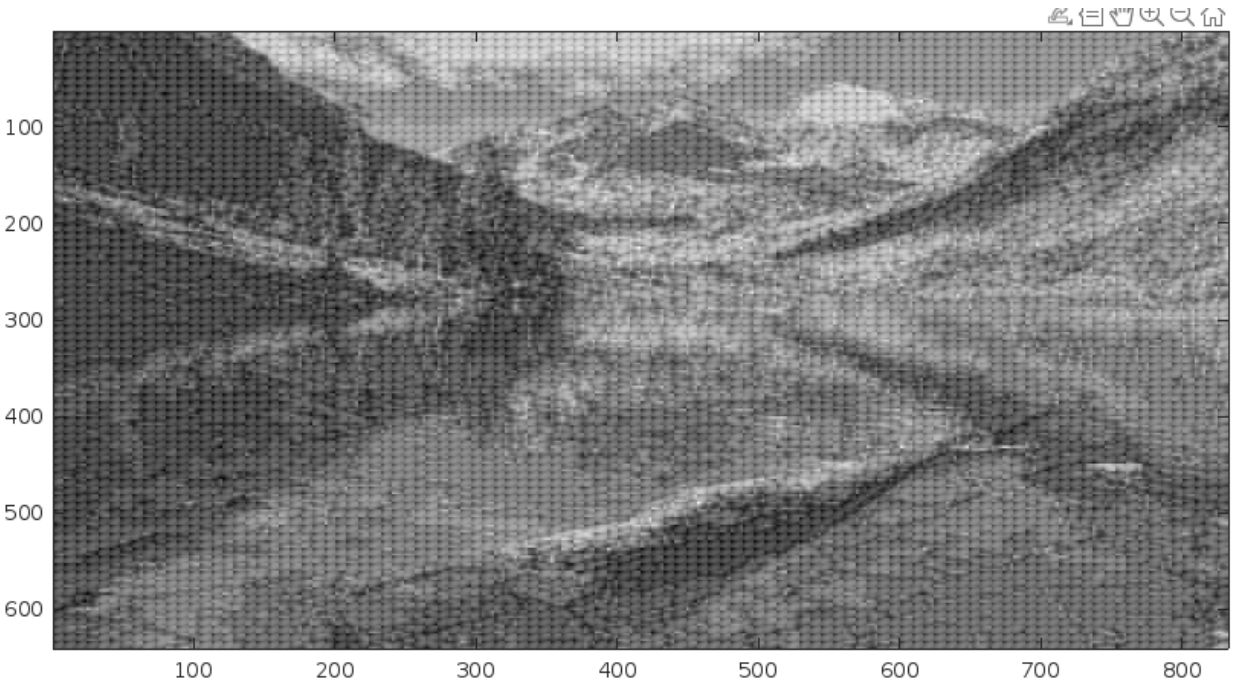
c

- Compute the resulting bitrate
  - For a 640*832 image, the bit needed to store is $(3 * 1 + 2 * 9) * 80 * 104 = 174720$
  - bitrate = $\frac{257920}{640*832} = 0.3281$
- and the compression ratio
  - compression ratio is 24.38
- Display the image

- 

- SNR = 9.4027

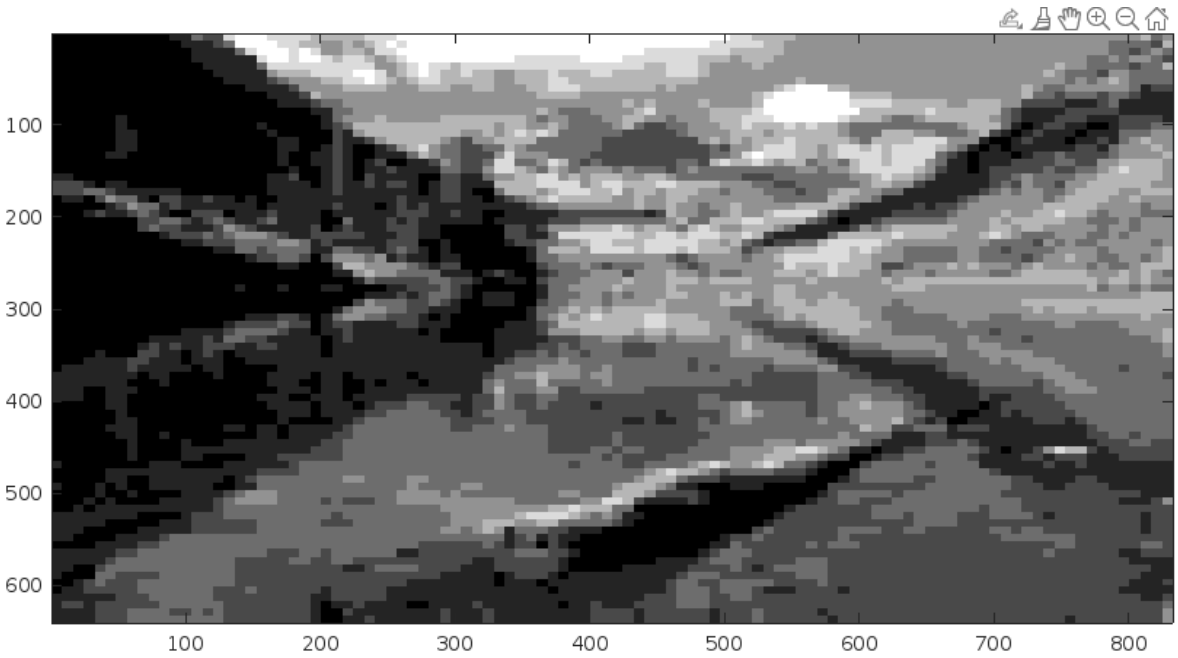
d

- Compute the resulting bitrate
  - For a 640*832 image, the bit needed to store is $(3 * 1 + 2 * 5) * 80 * 104 = 108160$
  - bitrate = $\frac{257920}{640*832} = 0.2031$
- and the compression ratio
  - compression ratio is 39.38
- Display the image
  - 

- SNR = 11.3568

e

- Compute the resulting bitrate
  - For a 640*832 image, the bit needed to store is $(3 * 1) * 80 * 104 = 24960$
  - bitrate = $\frac{257920}{640*832} = 0.0469$
- and the compression ratio

    - compression ratio is 170.67
- Dispaly the image
    - 

- SNR = 14.3281

f

	$\hat{G_{15}}$	$\hat{G_{10}}$	$\hat{G_6}$	$\hat{G_1}$
bitrate	0.4843	0.3281	0.2031	0.0469
SNR	7.6859	9.4027	11.3568	14.3281
visual quality	fine	fine	bad	worst

- We can see that with the drop of bitrate, the visual quality gets worse, but the SNR has increased.