

JPEG Encoder and Decoder

JPEG Encoder

0. Initiation (clear workspace)

```
clc;  
clear;  
close all;
```

1. Read and divide the image into blocks of 8x8 pixel

```
Image_Path = "D:\Zewail City\Fall 2023\cie 425\Project\Image Compression\Test_.jpg";  
Original_Image = imread(Image_Path);  
imshow(Original_Image);  
title("Original Image");
```

Original Image



```
Gray_Image = rgb2gray(Original_Image);  
imwrite(Gray_Image, 'Original_Grayscale.jpg', 'JPEG');  
imshow(Gray_Image)  
title("Grayscale Image");
```

Grayscale Image



```
% Divide the image into block of 8x8 pixels  
Image_Blocks = divideImageIntoBlocks(Gray_Image, 0)
```

```
Image_Blocks = 368x548 cell
```

```
...
```

	1	2	3	4	5	6	7	8
1	8x8 uint8							
2	8x8 uint8							
3	8x8 uint8							
4	8x8 uint8							
5	8x8 uint8							
6	8x8 uint8							
7	8x8 uint8							
8	8x8 uint8							
9	8x8 uint8							
10	8x8 uint8							
11	8x8 uint8							

	1	2	3	4	5	6	7	8
78	8x8 uint8							
79	8x8 uint8							
80	8x8 uint8							
81	8x8 uint8							
82	8x8 uint8							
83	8x8 uint8							
84	8x8 uint8							
85	8x8 uint8							
86	8x8 uint8							
87	8x8 uint8							
88	8x8 uint8							
89	8x8 uint8							
90	8x8 uint8							
91	8x8 uint8							
92	8x8 uint8							
93	8x8 uint8							
94	8x8 uint8							
95	8x8 uint8							
96	8x8 uint8							
97	8x8 uint8							
98	8x8 uint8							
99	8x8 uint8							
100	8x8 uint8							

⋮

2. Perform DCT on each block

```
image_in_freq_domain = DCT(Image_Blocks)
```

```
image_in_freq_domain = 368x548 cell
```

⋮

	1	2	3	4	5	6	7	8
1	8x8 double							
2	8x8 double							
3	8x8 double							
4	8x8 double							

% Validation

```
test block = {Image Blocks{1,1}};
```

```
test_block{1}
```

```
ans = 8x8 uint8 matrix
 95  85  80  67  55  59  64  68
 73  67  72  67  53  49  54  63
 67  57  62  63  51  44  47  59
 70  50  48  52  50  47  47  52
 65  44  38  42  47  51  48  44
 75  55  46  43  44  51  52  50
 88  69  59  50  44  49  55  59
 83  67  62  56  47  48  52  58
```

```
reconstructed_block = IDCT(DCT(test_block));
reconstructed_block{1};
% Calculate the RMSE
RMSE = sqrt(sum(sum((double(test_block{1})) - reconstructed_block{1}).^2))/numel(test_block))
```

```
RMSE = 2.7738e-13
```

```
Validation = horzcat( ...
    array2table(test_block{1}, 'VariableNames', compose('Original%d', 1:8)), ...
    array2table(reconstructed_block{1}, 'VariableNames', compose('Reconstructed%d', 1:8)))
```

```
Validation = 8x16 table
```

	Original1	Original2	Original3	Original4	Original5	Original6
1	95	85	80	67	55	59
2	73	67	72	67	53	49
3	67	57	62	63	51	44
4	70	50	48	52	50	47
5	65	44	38	42	47	51
6	75	55	46	43	44	51
7	88	69	59	50	44	49
8	83	67	62	56	47	48

```
% The validation using a single 8x8 block is to ensure that the output
% after performing DCT and IDCT restores the original pixel values.
```

3. Perform the quantization step per 8x8 block using at least two quantization tables

Low Compression

High Compression

1	1	1	1	1	2	2	4
1	1	1	1	1	2	2	4
1	1	1	1	2	2	2	4
1	1	1	1	2	2	4	8
1	1	2	2	2	2	4	8
2	2	2	2	2	4	8	8
2	2	2	4	4	8	8	16
4	4	4	4	8	8	16	16

1	2	4	8	16	32	64	128
2	4	4	8	16	32	64	128
4	4	8	16	32	64	128	128
8	8	16	32	64	128	128	256
16	16	32	64	128	128	256	256
32	32	64	128	128	256	256	256
64	64	128	128	256	256	256	256
128	128	128	256	256	256	256	256

```

Low_Compression_Quant_Table = [1, 1, 1, 1, 1, 1, 2, 2, 4;
                               1, 1, 1, 1, 1, 1, 2, 2, 4;
                               1, 1, 1, 1, 2, 2, 2, 2, 4;
                               1, 1, 1, 1, 2, 2, 4, 8;
                               1, 1, 2, 2, 2, 2, 4, 8;
                               2, 2, 2, 2, 2, 4, 8, 8;
                               2, 2, 2, 4, 4, 8, 8, 16;
                               4, 4, 4, 4, 8, 8, 16, 16];
High_Compression_Quant_Table = [1, 2, 4, 8, 16, 32, 64, 128;
                                 2, 4, 4, 8, 16, 32, 64, 128;
                                 4, 4, 8, 16, 32, 64, 128, 128;
                                 8, 8, 16, 32, 64, 128, 128, 256;
                                 16, 16, 32, 64, 128, 128, 256, 256;
                                 32, 32, 64, 128, 128, 256, 256, 256;
                                 64, 64, 128, 128, 256, 256, 256, 256;
                                 128, 128, 128, 256, 256, 256, 256, 256];
Quantization_Table = Low_Compression_Quant_Table

```

```

Quantization_Table = 8x8
 1   1   1   1   1   2   2   4
 1   1   1   1   1   2   2   4
 1   1   1   1   2   2   2   4
 1   1   1   1   2   2   4   8
 1   1   2   2   2   2   4   8
 2   2   2   2   2   4   8   8
 2   2   2   4   4   8   8   16
 4   4   4   4   8   8   16   16

```

```
Quantized_Blocks = Quantization(image_in_freq_domain, Quantization_Table)
```

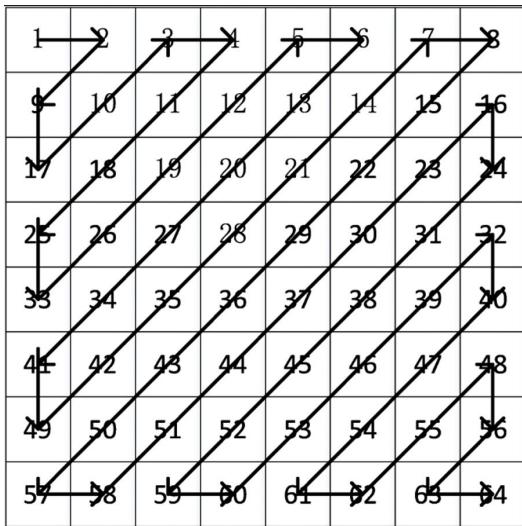
```
Quantized_Blocks = 368x548 cell
```

	1	2	3	4	5	6	7	8
1	8x8 double							
2	8x8 double							
3	8x8 double							

•
•
•

4. Transform each 2D block into 1D vector

This part and part No. 9 is inspired from the following figure:



```
TwoD_To_1D = From_2D_To_1D(Quantized_Blocks)
```

```
TwoD_To_1D = 368x548 cell
```

	1	2	3	4	5	6	7	8
1	1x64 double							
2	1x64 double							
3	1x64 double							
4	1x64 double							
5	1x64 double							
6	1x64 double							
7	1x64 double							
8	1x64 double							
9	1x64 double							
10	1x64 double							
11	1x64 double							
12	1x64 double							
13	1x64 double							
14	1x64 double							
15	1x64 double							
16	1x64 double							
17	1x64 double							
18	1x64 double							
19	1x64 double							

	1	2	3	4	5	6	7	8
86	1x64 double							
87	1x64 double							
88	1x64 double							
89	1x64 double							
90	1x64 double							
91	1x64 double							
92	1x64 double							
93	1x64 double							
94	1x64 double							
95	1x64 double							
96	1x64 double							
97	1x64 double							
98	1x64 double							
99	1x64 double							
100	1x64 double							
	⋮							

5. Perform run-length encoding

```
Run_Length_Encoded = run_length(TwoD_To_1D)
```

```
Run_Length_Encoded = 368×548 cell
```

⋮

	1	2	3	4	5	6	7	8
1	1x41 double	1x40 double	1x36 double	1x41 double	1x40 double	1x42 double	1x43 double	1x45 double
2	1x30 double	1x46 double	1x43 double	1x37 double	1x40 double	1x41 double	1x37 double	1x40 double
3	1x32 double	1x33 double	1x34 double	1x38 double	1x45 double	1x44 double	1x44 double	1x41 double
4	1x27 double	1x39 double	1x36 double	1x39 double	1x43 double	1x37 double	1x41 double	1x42 double
5	1x34 double	1x35 double	1x40 double	1x45 double	1x36 double	1x37 double	1x33 double	1x29 double
6	1x28 double	1x38 double	1x31 double	1x37 double	1x33 double	1x40 double	1x42 double	1x34 double
7	1x33 double	1x34 double	1x37 double	1x27 double	1x35 double	1x34 double	1x34 double	1x34 double
8	1x31 double	1x33 double	1x38 double	1x26 double	1x37 double	1x29 double	1x34 double	1x34 double
9	1x24 double	1x35 double	1x41 double	1x34 double	1x40 double	1x32 double	1x30 double	1x30 double
10	1x30 double	1x35 double	1x35 double	1x34 double	1x34 double	1x34 double	1x38 double	1x26 double
11	1x28 double	1x33 double	1x40 double	1x36 double	1x29 double	1x37 double	1x39 double	1x32 double
12	1x25 double	1x31 double	1x31 double	1x31 double	1x42 double	1x47 double	1x35 double	1x40 double

	1	2	3	4	5	6	7	8
13	1x31 double	1x24 double	1x31 double	1x34 double	1x40 double	1x41 double	1x38 double	1x34 double
14	1x29 double	1x32 double	1x36 double	1x33 double	1x34 double	1x34 double	1x37 double	1x36 double
15	1x39 double	1x30 double	1x31 double	1x36 double	1x35 double	1x31 double	1x34 double	1x41 double
16	1x31 double	1x31 double	1x32 double	1x32 double	1x39 double	1x34 double	1x31 double	1x30 double
17	1x32 double	1x34 double	1x21 double	1x24 double	1x35 double	1x39 double	1x34 double	1x27 double
18	1x39 double	1x32 double	1x34 double	1x31 double	1x26 double	1x28 double	1x30 double	1x32 double
19	1x45 double	1x33 double	1x33 double	1x32 double	1x31 double	1x30 double	1x28 double	1x30 double
20	1x40 double	1x25 double	1x36 double	1x33 double	1x25 double	1x33 double	1x25 double	1x25 double
21	1x34 double	1x20 double	1x32 double	1x36 double	1x31 double	1x35 double	1x40 double	1x27 double
22	1x27 double	1x35 double	1x33 double	1x40 double	1x31 double	1x32 double	1x29 double	1x47 double
23	1x34 double	1x41 double	1x36 double	1x46 double	1x34 double	1x34 double	1x33 double	1x35 double
24	1x37 double	1x44 double	1x35 double	1x37 double	1x38 double	1x33 double	1x34 double	1x30 double
25	1x32 double	1x28 double	1x38 double	1x39 double	1x36 double	1x29 double	1x33 double	1x28 double
26	1x31 double	1x31 double	1x30 double	1x35 double	1x33 double	1x45 double	1x36 double	1x29 double
27	1x33 double	1x35 double	1x31 double	1x28 double	1x30 double	1x28 double	1x37 double	1x33 double
28	1x31 double	1x25 double	1x41 double	1x32 double	1x37 double	1x39 double	1x45 double	1x29 double
29	1x40 double	1x41 double	1x37 double	1x38 double	1x32 double	1x45 double	1x39 double	1x38 double
30	1x29 double	1x35 double	1x35 double	1x34 double	1x28 double	1x29 double	1x39 double	1x27 double
31	1x34 double	1x32 double	1x36 double	1x28 double	1x34 double	1x30 double	1x33 double	1x38 double
32	1x27 double	1x26 double	1x34 double	1x36 double	1x25 double	1x31 double	1x30 double	1x28 double
33	1x38 double	1x32 double	1x29 double	1x35 double	1x35 double	1x22 double	1x31 double	1x32 double
34	1x26 double	1x27 double	1x22 double	1x32 double	1x29 double	1x40 double	1x32 double	1x29 double
35	1x33 double	1x28 double	1x36 double	1x31 double	1x32 double	1x32 double	1x28 double	1x29 double
36	1x27 double	1x30 double	1x29 double	1x30 double	1x29 double	1x24 double	1x32 double	1x25 double
37	1x35 double	1x31 double	1x30 double	1x31 double	1x30 double	1x27 double	1x25 double	1x27 double
38	1x35 double	1x35 double	1x31 double	1x27 double	1x29 double	1x28 double	1x31 double	1x23 double
39	1x37 double	1x32 double	1x25 double	1x31 double	1x21 double	1x21 double	1x27 double	1x32 double
40	1x33 double	1x40 double	1x28 double	1x24 double	1x20 double	1x24 double	1x25 double	1x27 double
41	1x33 double	1x31 double	1x34 double	1x25 double	1x20 double	1x20 double	1x25 double	1x27 double
42	1x35 double	1x33 double	1x22 double	1x29 double	1x29 double	1x29 double	1x31 double	1x29 double
43	1x39 double	1x28 double	1x30 double	1x22 double	1x34 double	1x34 double	1x26 double	1x33 double
44	1x32 double	1x26 double	1x29 double	1x24 double	1x29 double	1x32 double	1x29 double	1x33 double
45	1x33 double	1x32 double	1x36 double	1x31 double	1x37 double	1x34 double	1x38 double	1x33 double

	1	2	3	4	5	6	7	8
46	1x39 double	1x34 double	1x28 double	1x31 double	1x28 double	1x31 double	1x33 double	1x25 double
47	1x37 double	1x33 double	1x31 double	1x30 double	1x29 double	1x41 double	1x42 double	1x33 double
48	1x45 double	1x44 double	1x32 double	1x24 double	1x31 double	1x30 double	1x31 double	1x28 double
49	1x46 double	1x39 double	1x34 double	1x38 double	1x32 double	1x29 double	1x32 double	1x30 double
50	1x40 double	1x39 double	1x32 double	1x41 double	1x33 double	1x28 double	1x34 double	1x32 double
51	1x40 double	1x37 double	1x36 double	1x37 double	1x30 double	1x34 double	1x27 double	1x39 double
52	1x33 double	1x29 double	1x30 double	1x23 double	1x30 double	1x29 double	1x32 double	1x35 double
53	1x33 double	1x30 double	1x33 double	1x31 double	1x29 double	1x36 double	1x49 double	1x46 double
54	1x29 double	1x29 double	1x41 double	1x36 double	1x42 double	1x42 double	1x45 double	1x42 double
55	1x29 double	1x33 double	1x38 double	1x40 double	1x47 double	1x42 double	1x53 double	1x58 double
56	1x43 double	1x43 double	1x31 double	1x31 double	1x43 double	1x36 double	1x51 double	1x43 double
57	1x40 double	1x30 double	1x36 double	1x30 double	1x25 double	1x22 double	1x34 double	1x44 double
58	1x42 double	1x35 double	1x35 double	1x37 double	1x35 double	1x29 double	1x34 double	1x43 double
59	1x37 double	1x44 double	1x36 double	1x45 double	1x46 double	1x37 double	1x39 double	1x48 double
60	1x36 double	1x34 double	1x38 double	1x41 double	1x39 double	1x45 double	1x46 double	1x48 double
61	1x34 double	1x47 double	1x40 double	1x37 double	1x35 double	1x31 double	1x35 double	1x36 double
62	1x38 double	1x43 double	1x41 double	1x37 double	1x27 double	1x30 double	1x36 double	1x51 double
63	1x28 double	1x39 double	1x41 double	1x47 double	1x43 double	1x41 double	1x44 double	1x39 double
64	1x42 double	1x40 double	1x54 double	1x40 double	1x49 double	1x51 double	1x48 double	1x53 double
65	1x41 double	1x37 double	1x47 double	1x57 double	1x49 double	1x40 double	1x44 double	1x50 double
66	1x36 double	1x37 double	1x45 double	1x48 double	1x46 double	1x41 double	1x44 double	1x54 double
67	1x31 double	1x31 double	1x41 double	1x46 double	1x43 double	1x37 double	1x49 double	1x44 double
68	1x36 double	1x33 double	1x42 double	1x29 double	1x54 double	1x46 double	1x38 double	1x46 double
69	1x37 double	1x38 double	1x49 double	1x43 double	1x48 double	1x37 double	1x34 double	1x41 double
70	1x36 double	1x47 double	1x42 double	1x42 double	1x40 double	1x37 double	1x34 double	1x25 double
71	1x29 double	1x36 double	1x38 double	1x37 double	1x28 double	1x33 double	1x35 double	1x35 double
72	1x42 double	1x40 double	1x42 double	1x44 double	1x40 double	1x46 double	1x42 double	1x38 double
73	1x54 double	1x39 double	1x41 double	1x42 double	1x39 double	1x39 double	1x40 double	1x50 double
74	1x45 double	1x43 double	1x40 double	1x48 double	1x54 double	1x39 double	1x35 double	1x48 double
75	1x45 double	1x38 double	1x34 double	1x41 double	1x39 double	1x37 double	1x43 double	1x54 double
76	1x52 double	1x41 double	1x41 double	1x40 double	1x34 double	1x46 double	1x38 double	1x43 double
77	1x45 double	1x37 double	1x43 double	1x39 double	1x44 double	1x44 double	1x38 double	1x38 double
78	1x39 double	1x30 double	1x31 double	1x37 double	1x34 double	1x33 double	1x50 double	1x47 double

	1	2	3	4	5	6	7	8
79	1x29 double	1x30 double	1x26 double	1x29 double	1x33 double	1x31 double	1x32 double	1x38 double
80	1x26 double	1x27 double	1x28 double	1x23 double	1x30 double	1x28 double	1x38 double	1x35 double
81	1x23 double	1x25 double	1x23 double	1x18 double	1x23 double	1x29 double	1x33 double	1x39 double
82	1x24 double	1x15 double	1x26 double	1x31 double	1x26 double	1x31 double	1x30 double	1x43 double
83	1x31 double	1x27 double	1x26 double	1x23 double	1x34 double	1x39 double	1x30 double	1x31 double
84	1x38 double	1x27 double	1x21 double	1x27 double	1x28 double	1x31 double	1x26 double	1x33 double
85	1x25 double	1x31 double	1x25 double	1x28 double	1x38 double	1x25 double	1x27 double	1x26 double
86	1x25 double	1x19 double	1x28 double	1x30 double	1x45 double	1x35 double	1x38 double	1x35 double
87	1x33 double	1x19 double	1x42 double	1x41 double	1x35 double	1x43 double	1x58 double	1x39 double
88	1x31 double	1x35 double	1x33 double	1x41 double	1x40 double	1x41 double	1x44 double	1x45 double
89	1x34 double	1x40 double	1x39 double	1x49 double	1x54 double	1x42 double	1x43 double	1x41 double
90	1x26 double	1x41 double	1x45 double	1x40 double	1x46 double	1x43 double	1x43 double	1x39 double
91	1x36 double	1x45 double	1x23 double	1x24 double	1x25 double	1x24 double	1x28 double	1x27 double
92	1x38 double	1x46 double	1x23 double	1x29 double	1x19 double	1x30 double	1x28 double	1x26 double
93	1x48 double	1x30 double	1x33 double	1x25 double	1x20 double	1x23 double	1x21 double	1x24 double
94	1x31 double	1x29 double	1x21 double	1x22 double	1x26 double	1x21 double	1x29 double	1x22 double
95	1x41 double	1x26 double	1x24 double	1x16 double	1x22 double	1x22 double	1x34 double	1x26 double
96	1x43 double	1x23 double	1x35 double	1x35 double	1x34 double	1x32 double	1x29 double	1x17 double
97	1x44 double	1x43 double	1x34 double	1x41 double	1x23 double	1x24 double	1x33 double	1x20 double
98	1x43 double	1x29 double	1x27 double	1x27 double	1x29 double	1x21 double	1x30 double	1x30 double
99	1x40 double	1x52 double	1x47 double	1x38 double	1x20 double	1x23 double	1x28 double	1x27 double
100	1x54 double	1x47 double	1x40 double	1x41 double	1x37 double	1x39 double	1x35 double	1x34 double
	:							
	:							

6. Use Entropy encoder

```
Entropy_Encoder = "Huffman"
```

```
Entropy_Encoder =
"Huffman"
```

```
pre_entropy = pre_entropy_encoding(Run_Length_Encoded)
```

```
pre_entropy = 1x6818485
 368   -200    548   -200     57      8      5      9      0      1      7      1      -3    ...
```

```
if Entropy_Encoder == "Huffman"
    [tree, encoded_data, ~] = encode_Huffman(pre_entropy);
    print_encoded_data(encoded_data(1:10))
else
```

```
% Use Finite Precision Arithmetic
end
```

00100010001100010010101000000100010001100010010111000000100111011001101100010001000011101

JPEG Decoder

7. Use Huffman decoder

```
if Entropy_Encoder == "Huffman"
    decoded_data = Huffman_Decode(encoded_data, tree)
    received_image = post_entropy_encoding(decoded_data(5:end-1), decoded_data(1),
decoded_data(3))
else
    % Use Finite Precision Arithmetic
end
```

decoded_data = 1x6818485
368 -200 548 -200 57 8 5 9 0 1 7 1 -3 ...
received_image = 368x548 cell

...

	1	2	3	4	5	6	7	8
1	1x41 double	1x40 double	1x36 double	1x41 double	1x40 double	1x42 double	1x43 double	1x45 double
2	1x30 double	1x46 double	1x43 double	1x37 double	1x40 double	1x41 double	1x37 double	1x40 double
3	1x32 double	1x33 double	1x34 double	1x38 double	1x45 double	1x44 double	1x44 double	1x41 double
4	1x27 double	1x39 double	1x36 double	1x39 double	1x43 double	1x37 double	1x41 double	1x42 double
5	1x34 double	1x35 double	1x40 double	1x45 double	1x36 double	1x37 double	1x33 double	1x29 double
6	1x28 double	1x38 double	1x31 double	1x37 double	1x33 double	1x40 double	1x42 double	1x34 double
7	1x33 double	1x34 double	1x37 double	1x27 double	1x35 double	1x34 double	1x34 double	1x34 double
8	1x31 double	1x33 double	1x38 double	1x26 double	1x37 double	1x29 double	1x34 double	1x34 double
9	1x24 double	1x35 double	1x41 double	1x34 double	1x40 double	1x32 double	1x30 double	1x30 double
10	1x30 double	1x35 double	1x35 double	1x34 double	1x34 double	1x34 double	1x38 double	1x26 double
11	1x28 double	1x33 double	1x40 double	1x36 double	1x29 double	1x37 double	1x39 double	1x32 double
12	1x25 double	1x31 double	1x31 double	1x31 double	1x42 double	1x47 double	1x35 double	1x40 double
13	1x31 double	1x24 double	1x31 double	1x34 double	1x40 double	1x41 double	1x38 double	1x34 double
14	1x29 double	1x32 double	1x36 double	1x33 double	1x34 double	1x34 double	1x37 double	1x36 double
15	1x39 double	1x30 double	1x31 double	1x36 double	1x35 double	1x31 double	1x34 double	1x41 double
16	1x31 double	1x31 double	1x32 double	1x32 double	1x39 double	1x34 double	1x31 double	1x30 double
17	1x32 double	1x34 double	1x21 double	1x24 double	1x35 double	1x39 double	1x34 double	1x27 double
18	1x39 double	1x32 double	1x34 double	1x31 double	1x26 double	1x28 double	1x30 double	1x32 double
19	1x45 double	1x33 double	1x33 double	1x32 double	1x31 double	1x30 double	1x28 double	1x30 double
20	1x40 double	1x25 double	1x36 double	1x33 double	1x25 double	1x33 double	1x25 double	1x25 double

	1	2	3	4	5	6	7	8
21	1x34 double	1x20 double	1x32 double	1x36 double	1x31 double	1x35 double	1x40 double	1x27 double
22	1x27 double	1x35 double	1x33 double	1x40 double	1x31 double	1x32 double	1x29 double	1x47 double
23	1x34 double	1x41 double	1x36 double	1x46 double	1x34 double	1x34 double	1x33 double	1x35 double
24	1x37 double	1x44 double	1x35 double	1x37 double	1x38 double	1x33 double	1x34 double	1x30 double
25	1x32 double	1x28 double	1x38 double	1x39 double	1x36 double	1x29 double	1x33 double	1x28 double
26	1x31 double	1x31 double	1x30 double	1x35 double	1x33 double	1x45 double	1x36 double	1x29 double
27	1x33 double	1x35 double	1x31 double	1x28 double	1x30 double	1x28 double	1x37 double	1x33 double
28	1x31 double	1x25 double	1x41 double	1x32 double	1x37 double	1x39 double	1x45 double	1x29 double
29	1x40 double	1x41 double	1x37 double	1x38 double	1x32 double	1x45 double	1x39 double	1x38 double
30	1x29 double	1x35 double	1x35 double	1x34 double	1x28 double	1x29 double	1x39 double	1x27 double
31	1x34 double	1x32 double	1x36 double	1x28 double	1x34 double	1x30 double	1x33 double	1x38 double
32	1x27 double	1x26 double	1x34 double	1x36 double	1x25 double	1x31 double	1x30 double	1x28 double
33	1x38 double	1x32 double	1x29 double	1x35 double	1x35 double	1x22 double	1x31 double	1x32 double
34	1x26 double	1x27 double	1x22 double	1x32 double	1x29 double	1x40 double	1x32 double	1x29 double
35	1x33 double	1x28 double	1x36 double	1x31 double	1x32 double	1x32 double	1x28 double	1x29 double
36	1x27 double	1x30 double	1x29 double	1x30 double	1x29 double	1x24 double	1x32 double	1x25 double
37	1x35 double	1x31 double	1x30 double	1x31 double	1x30 double	1x27 double	1x25 double	1x27 double
38	1x35 double	1x35 double	1x31 double	1x27 double	1x29 double	1x28 double	1x31 double	1x23 double
39	1x37 double	1x32 double	1x25 double	1x31 double	1x21 double	1x21 double	1x27 double	1x32 double
40	1x33 double	1x40 double	1x28 double	1x24 double	1x20 double	1x24 double	1x25 double	1x27 double
41	1x33 double	1x31 double	1x34 double	1x25 double	1x20 double	1x20 double	1x25 double	1x27 double
42	1x35 double	1x33 double	1x22 double	1x29 double	1x29 double	1x29 double	1x31 double	1x29 double
43	1x39 double	1x28 double	1x30 double	1x22 double	1x34 double	1x34 double	1x26 double	1x33 double
44	1x32 double	1x26 double	1x29 double	1x24 double	1x29 double	1x32 double	1x29 double	1x33 double
45	1x33 double	1x32 double	1x36 double	1x31 double	1x37 double	1x34 double	1x38 double	1x33 double
46	1x39 double	1x34 double	1x28 double	1x31 double	1x28 double	1x31 double	1x33 double	1x25 double
47	1x37 double	1x33 double	1x31 double	1x30 double	1x29 double	1x41 double	1x42 double	1x33 double
48	1x45 double	1x44 double	1x32 double	1x24 double	1x31 double	1x30 double	1x31 double	1x28 double
49	1x46 double	1x39 double	1x34 double	1x38 double	1x32 double	1x29 double	1x32 double	1x30 double
50	1x40 double	1x39 double	1x32 double	1x41 double	1x33 double	1x28 double	1x34 double	1x32 double
51	1x40 double	1x37 double	1x36 double	1x37 double	1x30 double	1x34 double	1x27 double	1x39 double
52	1x33 double	1x29 double	1x30 double	1x23 double	1x30 double	1x29 double	1x32 double	1x35 double
53	1x33 double	1x30 double	1x33 double	1x31 double	1x29 double	1x36 double	1x49 double	1x46 double

	1	2	3	4	5	6	7	8
54	1x29 double	1x29 double	1x41 double	1x36 double	1x42 double	1x42 double	1x45 double	1x42 double
55	1x29 double	1x33 double	1x38 double	1x40 double	1x47 double	1x42 double	1x53 double	1x58 double
56	1x43 double	1x43 double	1x31 double	1x31 double	1x43 double	1x36 double	1x51 double	1x43 double
57	1x40 double	1x30 double	1x36 double	1x30 double	1x25 double	1x22 double	1x34 double	1x44 double
58	1x42 double	1x35 double	1x35 double	1x37 double	1x35 double	1x29 double	1x34 double	1x43 double
59	1x37 double	1x44 double	1x36 double	1x45 double	1x46 double	1x37 double	1x39 double	1x48 double
60	1x36 double	1x34 double	1x38 double	1x41 double	1x39 double	1x45 double	1x46 double	1x48 double
61	1x34 double	1x47 double	1x40 double	1x37 double	1x35 double	1x31 double	1x35 double	1x36 double
62	1x38 double	1x43 double	1x41 double	1x37 double	1x27 double	1x30 double	1x36 double	1x51 double
63	1x28 double	1x39 double	1x41 double	1x47 double	1x43 double	1x41 double	1x44 double	1x39 double
64	1x42 double	1x40 double	1x54 double	1x40 double	1x49 double	1x51 double	1x48 double	1x53 double
65	1x41 double	1x37 double	1x47 double	1x57 double	1x49 double	1x40 double	1x44 double	1x50 double
66	1x36 double	1x37 double	1x45 double	1x48 double	1x46 double	1x41 double	1x44 double	1x54 double
67	1x31 double	1x31 double	1x41 double	1x46 double	1x43 double	1x37 double	1x49 double	1x44 double
68	1x36 double	1x33 double	1x42 double	1x29 double	1x54 double	1x46 double	1x38 double	1x46 double
69	1x37 double	1x38 double	1x49 double	1x43 double	1x48 double	1x37 double	1x34 double	1x41 double
70	1x36 double	1x47 double	1x42 double	1x42 double	1x40 double	1x37 double	1x34 double	1x25 double
71	1x29 double	1x36 double	1x38 double	1x37 double	1x28 double	1x33 double	1x35 double	1x35 double
72	1x42 double	1x40 double	1x42 double	1x44 double	1x40 double	1x46 double	1x42 double	1x38 double
73	1x54 double	1x39 double	1x41 double	1x42 double	1x39 double	1x39 double	1x40 double	1x50 double
74	1x45 double	1x43 double	1x40 double	1x48 double	1x54 double	1x39 double	1x35 double	1x48 double
75	1x45 double	1x38 double	1x34 double	1x41 double	1x39 double	1x37 double	1x43 double	1x54 double
76	1x52 double	1x41 double	1x41 double	1x40 double	1x34 double	1x46 double	1x38 double	1x43 double
77	1x45 double	1x37 double	1x43 double	1x39 double	1x44 double	1x44 double	1x38 double	1x38 double
78	1x39 double	1x30 double	1x31 double	1x37 double	1x34 double	1x33 double	1x50 double	1x47 double
79	1x29 double	1x30 double	1x26 double	1x29 double	1x33 double	1x31 double	1x32 double	1x38 double
80	1x26 double	1x27 double	1x28 double	1x23 double	1x30 double	1x28 double	1x38 double	1x35 double
81	1x23 double	1x25 double	1x23 double	1x18 double	1x23 double	1x29 double	1x33 double	1x39 double
82	1x24 double	1x15 double	1x26 double	1x31 double	1x26 double	1x31 double	1x30 double	1x43 double
83	1x31 double	1x27 double	1x26 double	1x23 double	1x34 double	1x39 double	1x30 double	1x31 double
84	1x38 double	1x27 double	1x21 double	1x27 double	1x28 double	1x31 double	1x26 double	1x33 double
85	1x25 double	1x31 double	1x25 double	1x28 double	1x38 double	1x25 double	1x27 double	1x26 double
86	1x25 double	1x19 double	1x28 double	1x30 double	1x45 double	1x35 double	1x38 double	1x35 double

	1	2	3	4	5	6	7	8
87	1x33 double	1x19 double	1x42 double	1x41 double	1x35 double	1x43 double	1x58 double	1x39 double
88	1x31 double	1x35 double	1x33 double	1x41 double	1x40 double	1x41 double	1x44 double	1x45 double
89	1x34 double	1x40 double	1x39 double	1x49 double	1x54 double	1x42 double	1x43 double	1x41 double
90	1x26 double	1x41 double	1x45 double	1x40 double	1x46 double	1x43 double	1x43 double	1x39 double
91	1x36 double	1x45 double	1x23 double	1x24 double	1x25 double	1x24 double	1x28 double	1x27 double
92	1x38 double	1x46 double	1x23 double	1x29 double	1x19 double	1x30 double	1x28 double	1x26 double
93	1x48 double	1x30 double	1x33 double	1x25 double	1x20 double	1x23 double	1x21 double	1x24 double
94	1x31 double	1x29 double	1x21 double	1x22 double	1x26 double	1x21 double	1x29 double	1x22 double
95	1x41 double	1x26 double	1x24 double	1x16 double	1x22 double	1x22 double	1x34 double	1x26 double
96	1x43 double	1x23 double	1x35 double	1x35 double	1x34 double	1x32 double	1x29 double	1x17 double
97	1x44 double	1x43 double	1x34 double	1x41 double	1x23 double	1x24 double	1x33 double	1x20 double
98	1x43 double	1x29 double	1x27 double	1x27 double	1x29 double	1x21 double	1x30 double	1x30 double
99	1x40 double	1x52 double	1x47 double	1x38 double	1x20 double	1x23 double	1x28 double	1x27 double
100	1x54 double	1x47 double	1x40 double	1x41 double	1x37 double	1x39 double	1x35 double	1x34 double

:

8. Perform run-length decoding

```
Run_Length_Decoded = inv_run_length(received_image)
```

```
Run_Length_Decoded = 368x548 cell
```

...

	1	2	3	4	5	6	7	8
1	1x64 double							
2	1x64 double							
3	1x64 double							
4	1x64 double							
5	1x64 double							
6	1x64 double							
7	1x64 double							
8	1x64 double							
9	1x64 double							
10	1x64 double							
11	1x64 double							
12	1x64 double							
13	1x64 double							

	1	2	3	4	5	6	7	8
80	1x64 double							
81	1x64 double							
82	1x64 double							
83	1x64 double							
84	1x64 double							
85	1x64 double							
86	1x64 double							
87	1x64 double							
88	1x64 double							
89	1x64 double							
90	1x64 double							
91	1x64 double							
92	1x64 double							
93	1x64 double							
94	1x64 double							
95	1x64 double							
96	1x64 double							
97	1x64 double							
98	1x64 double							
99	1x64 double							
100	1x64 double							

:

9. Transform each 1D vector into 2D block

```
OneD_To_2D = From_1D_To_2D(Run_Length_Decoded)
```

```
OneD_To_2D = 368x548 cell
```

...

	1	2	3	4	5	6	7	8
1	8x8 double							
2	8x8 double							
3	8x8 double							
4	8x8 double							
5	8x8 double							
6	8x8 double							

	1	2	3	4	5	6	7	8
73	8x8 double							
74	8x8 double							
75	8x8 double							
76	8x8 double							
77	8x8 double							
78	8x8 double							
79	8x8 double							
80	8x8 double							
81	8x8 double							
82	8x8 double							
83	8x8 double							
84	8x8 double							
85	8x8 double							
86	8x8 double							
87	8x8 double							
88	8x8 double							
89	8x8 double							
90	8x8 double							
91	8x8 double							
92	8x8 double							
93	8x8 double							
94	8x8 double							
95	8x8 double							
96	8x8 double							
97	8x8 double							
98	8x8 double							
99	8x8 double							
100	8x8 double							

:

10. Multiply each group by the quantization table

```
Dequantization_out = Dequantization(OneD_To_2D, Quantization_Table)
```

```
Dequantization_out = 368x548 cell
```

...

	1	2	3	4	5	6	7	8
100	8x8 double							

:

11. Perform IDCT on each block

```
image_in_spatial_domain = IDCT(Dequantization_out)
```

```
image_in_spatial_domain = 368x548 cell
```

	1	2	3	4	5	6	7	8
1	8x8 double							
2	8x8 double							
3	8x8 double							
4	8x8 double							
5	8x8 double							
6	8x8 double							
7	8x8 double							
8	8x8 double							
9	8x8 double							
10	8x8 double							
11	8x8 double							
12	8x8 double							
13	8x8 double							
14	8x8 double							
15	8x8 double							
16	8x8 double							
17	8x8 double							
18	8x8 double							
19	8x8 double							
20	8x8 double							
21	8x8 double							
22	8x8 double							
23	8x8 double							
24	8x8 double							
25	8x8 double							
26	8x8 double							

	1	2	3	4	5	6	7	8
93	8x8 double							
94	8x8 double							
95	8x8 double							
96	8x8 double							
97	8x8 double							
98	8x8 double							
99	8x8 double							
100	8x8 double							

⋮

12. Combine the 8x8 pixel groups into a single image and save it back to a file

```
Received_Image = combineBlocks(image_in_spatial_domain);
imshow(Received_Image)
title("Received Image");
```

Received Image



```
imwrite(Received_Image, ...)
```

```
'result.jpg','JPEG');
```

13. Compare the original image with the compressed image when using each quantization table

```
CompRatio = getCompRatio(encoded_data, size(Gray_Image, 1), size(Gray_Image, 2));  
subplot(1,2,1)  
imshow(Gray_Image)  
title("Original Image");  
subplot(1,2,2)  
imshow(Received_Image)  
title("Received Image");
```

Original Image



Received Image



```
fprintf("Compression Ratio = %.2f%%", CompRatio*100);
```

Compression Ratio = 71.62%