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كلية الحاسبات
و المعلومات

Vector Quantization
(Using LBG Algorithm with Splitting)

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Original Image

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Divide Image into Blocks (Vectors)

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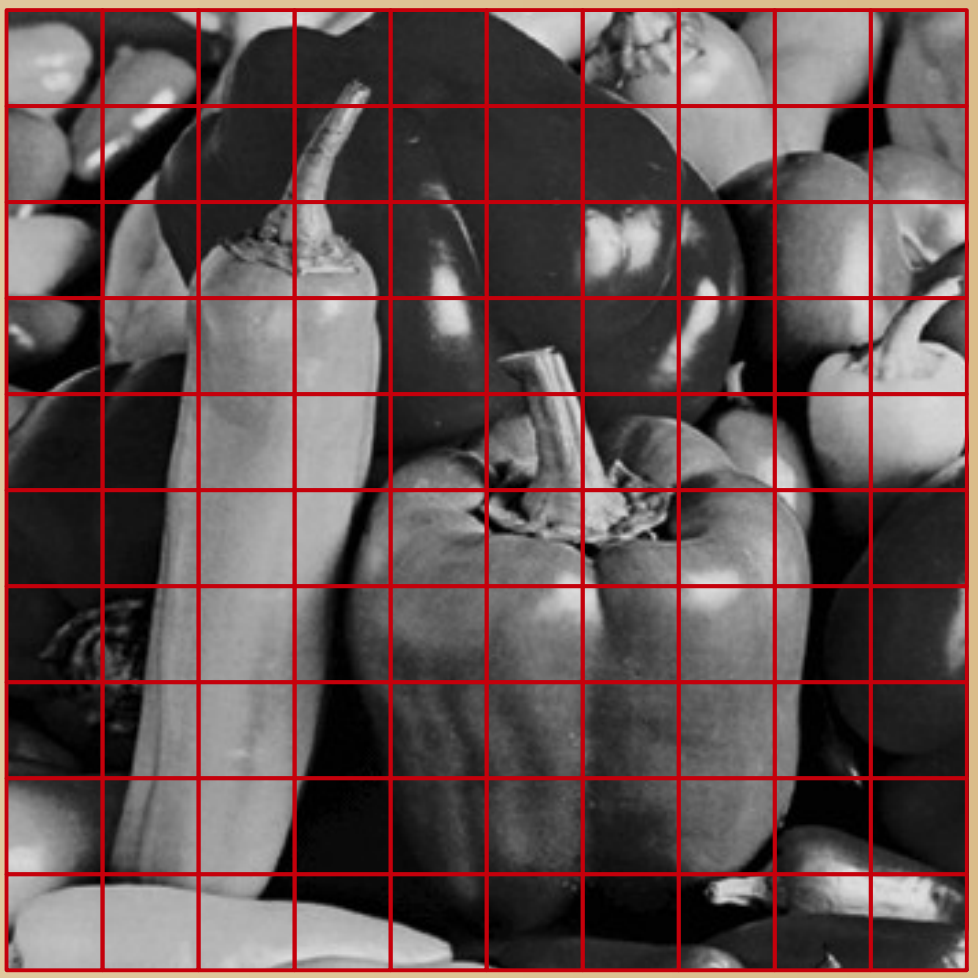

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Generate Best “K” Vectors that can be used to Re-Construct Original Image

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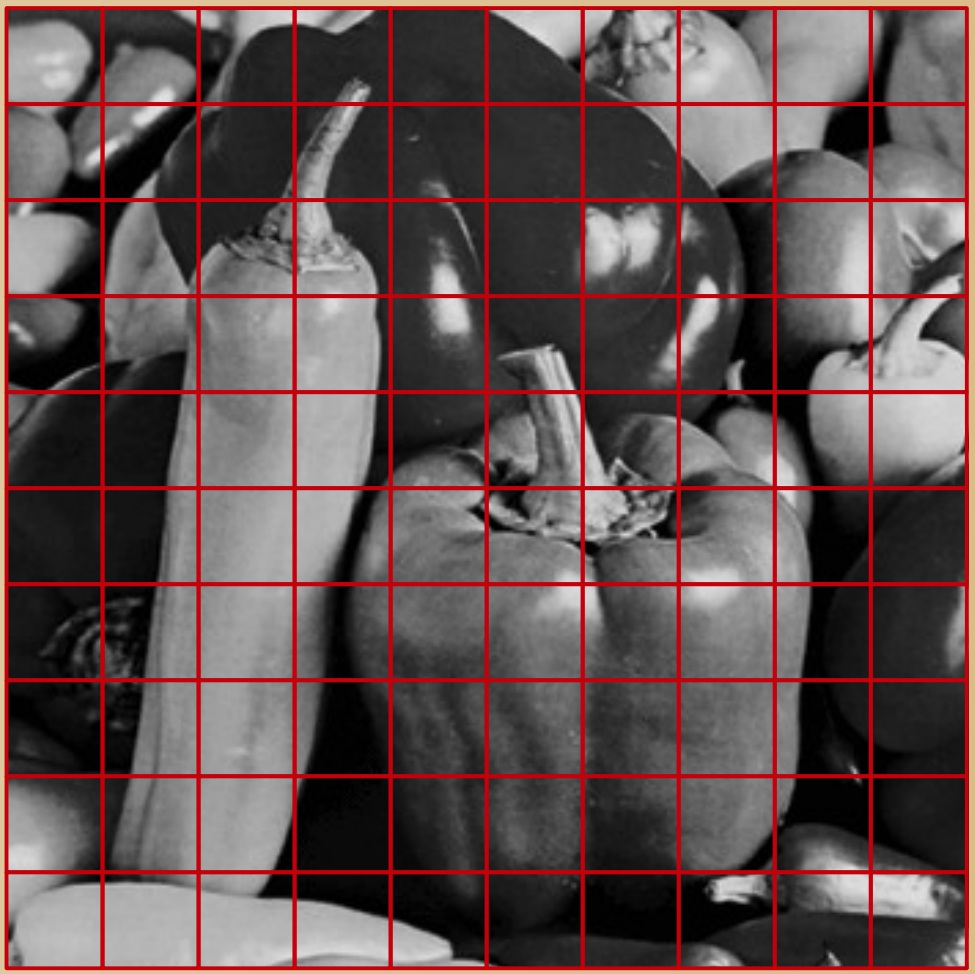

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For Each Block in the Image, Select the Nearest Vector (Using Euclidean Distance)

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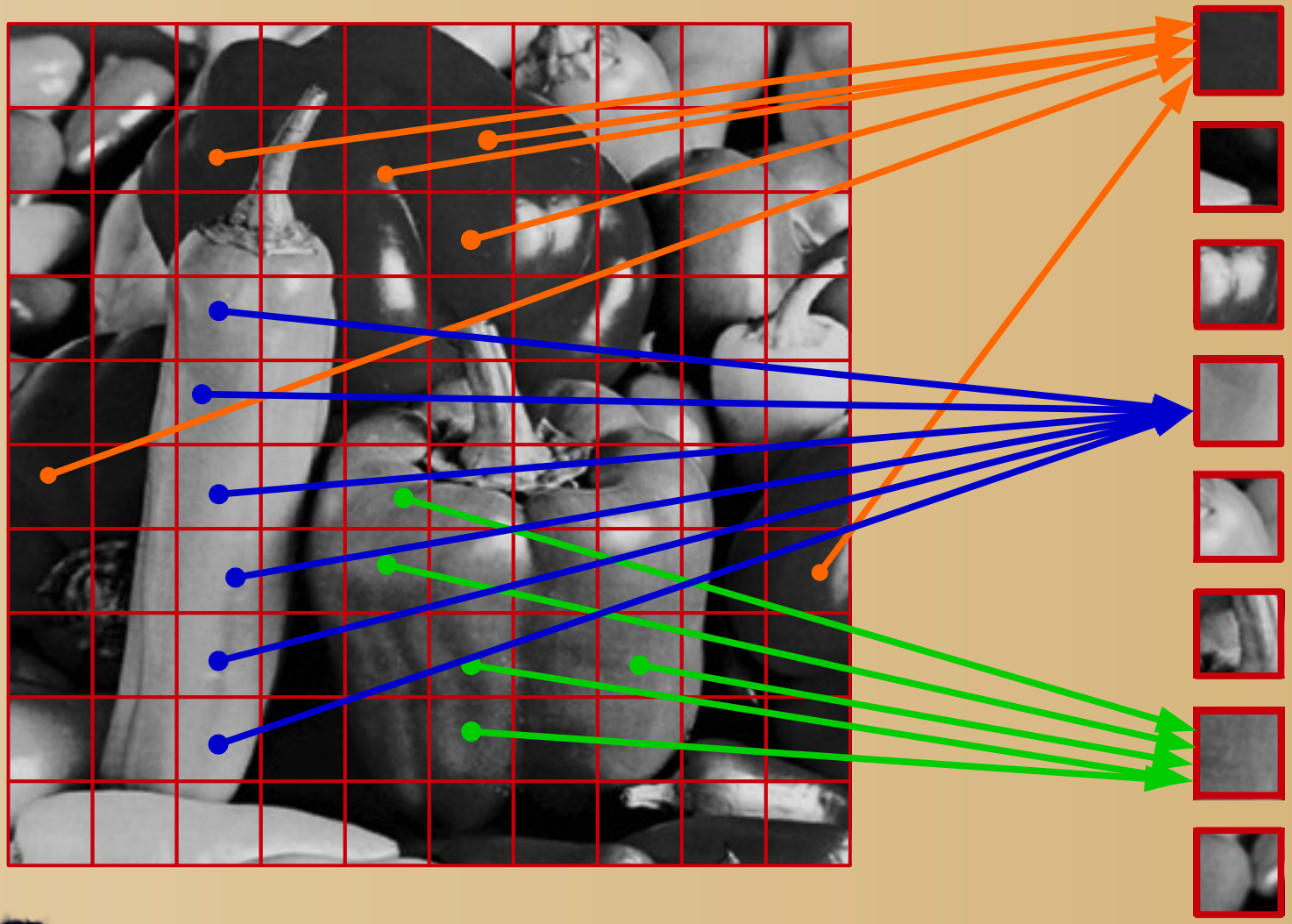

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Label each Block in the image with INDEX of Nearest Vector (in the Codebook)

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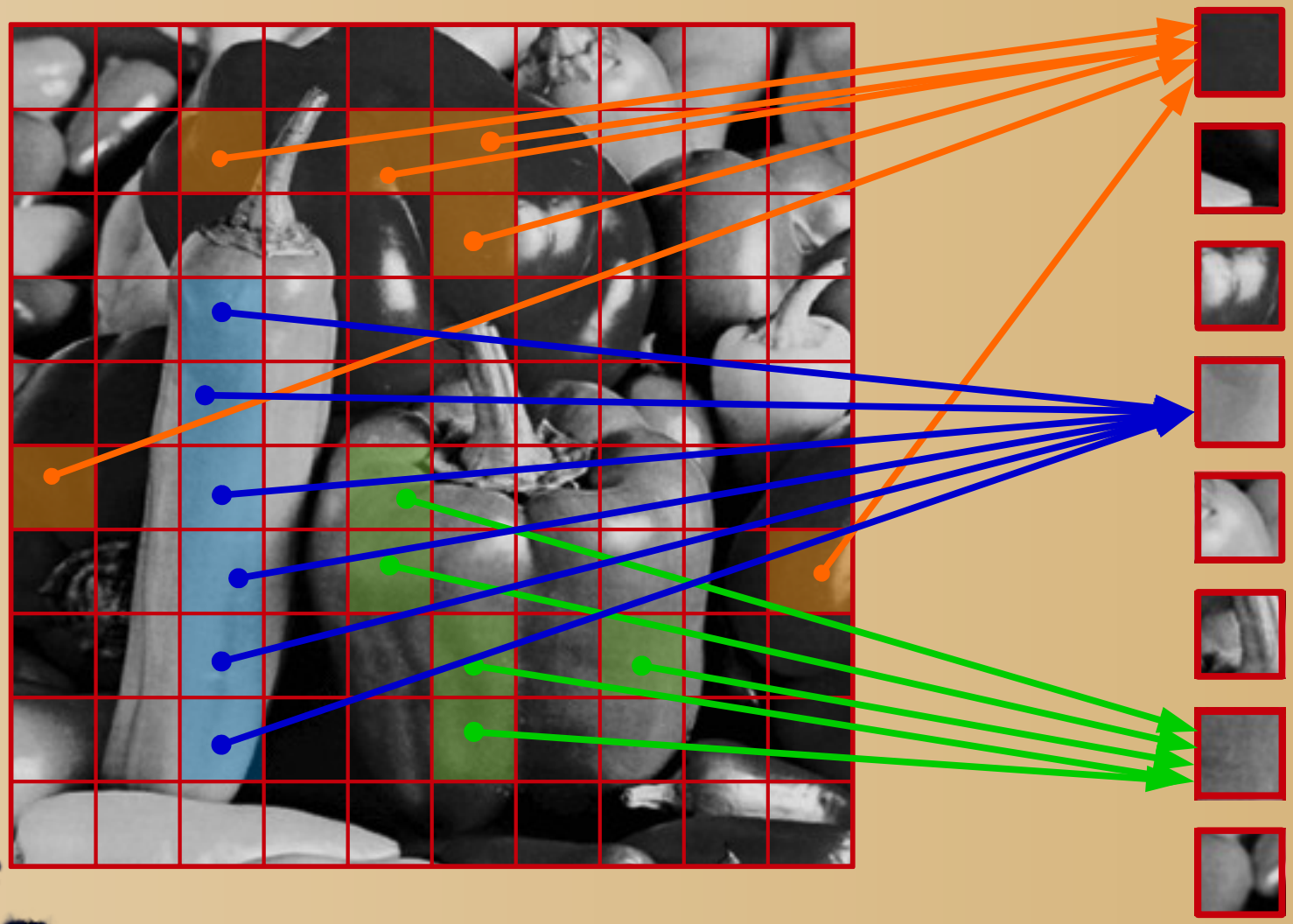

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Label each Block in the image with INDEX of Nearest Vector (in the Codebook)

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Compression Ratio

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In order to Re-Construct the Image, it is required to have:

- **All Labels** (one label for each BLOCK in the Image)
- **The Codebook itself** which consists of K Vectors, each vector is a small Image with size equal to BLOCK size

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Compression Ratio

Example:

The original **GRAY** image is **600*600 pixels** (each pixel is saved in one byte)

The image is divided into **Blocks each of size 4*4 pixels**

The Codebook (which will be used to Reconsturct the image) consists of 32 Vectors (**32 blocks each of size 4*4**)

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Compression Ratio

Example:

Number Blocks in the image= (600*600)/ (4*4)=22500 Blocks

Number of labels = Number of Blocks = 22500 Labels

(Remember: Each label is Index in the Codebook)

As **Number of Vectors in the codebook = 32**, Indexes will range from 0 to 31 (from 00000 to 11111 Binary)

In other words, **each index can be saved in 5 Bits**

(this means **each label is 5 bits**)

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Compression Ratio

Exact Compression Ratio:

Labels Size = Number of Labels * bits/Label = 22500 * 5 bits

=112500 bits (14063 Bytes)

Codebook Storage Size =

Number of Vectors * Vector Size (in pixels) * number of bits to save a pixel = 32 * (4*4) * 8 bits = 4096 bits (512 bytes)

Total Compressed Image Size = Label Size + Code book storage size

= 112500+ 4096 = 116596 bits (14575 bytes)

Original Image Size = 600 * 600 (pixels) * 8 bits/pixel = 2880000 bits (360000 Bytes)

Compression Ratio = Original / Compressed = 360000/14575 = 24.7:1

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Compression Ratio

Approximate Compression Ratio:

When Label Size is much greater than Codebook storage size, Codebook Storage size can be neglected during Compression ratio Calculations.

(Remember: Codebook Storage size is independent of Image size, number of Labels depends on Image Size.)

Labels Size = Number of Labels * bits/Label = 22500 * 5 bits =112500 bits (14063 Bytes)

Codebook Storage Size = 32 * (4*4) * 8 bits = 4096 bits (512 bytes) [can be neglected w.r.t 14063 bytes)

Total Compressed Image Size ~= Label Size =112500 bits (14063 bytes)

Original Image Size = 600 * 600 (pixels) * 8 bits/pixel = 2880000 bits (360000 Bytes)

Compression Ratio = Original / Compressed = 360000/14063 = 25.6:1

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Compression Ratio

Approximate Compression Ratio:

Also, Compression ratio can be calculated approximately on Block bases (not on image bases)

Each block in image is originally stored in (4*4) pixels * 8 bits/pixel

= 4*4*8=128 bits

After compression, Each block is substituted with Label of size 5 bits (as 2^5 = 32 vectors in the Codebook)

The compression ratio = 128: 5 = 25.6:1 (same as before)

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Compression Ratio

What if image is 6000 x 6000, Exact Compression Ratio:

Labels Size = Number of Labels * bits/Label = (6000*6000)/(4*4) * 5 bits

=11,250,000 bits (1,406,300 Bytes)

Codebook Storage Size =

Number of Vectors * Vector Size (in pixels) * number of bits to save a pixel = 32 * (4*4) * 8 bits = 4096 bits (512 bytes) [No change, Independent of Image Size]

Total Compressed Image Size = Label Size + Code book storage size

= 11250000+ 4096 = 11,254,096 bits (1,406,762 bytes ~=1,406,300)

Original Image Size = 6000 * 6000 (pixels) * 8 bits/pixel = 288000000 bits (36,000,000 Bytes)

Compression Ratio = Original / Compressed = 36,000,000/1,406,762 = 25.6:1

(Almost as Approximate Compression ratio)

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Image Reconsturction

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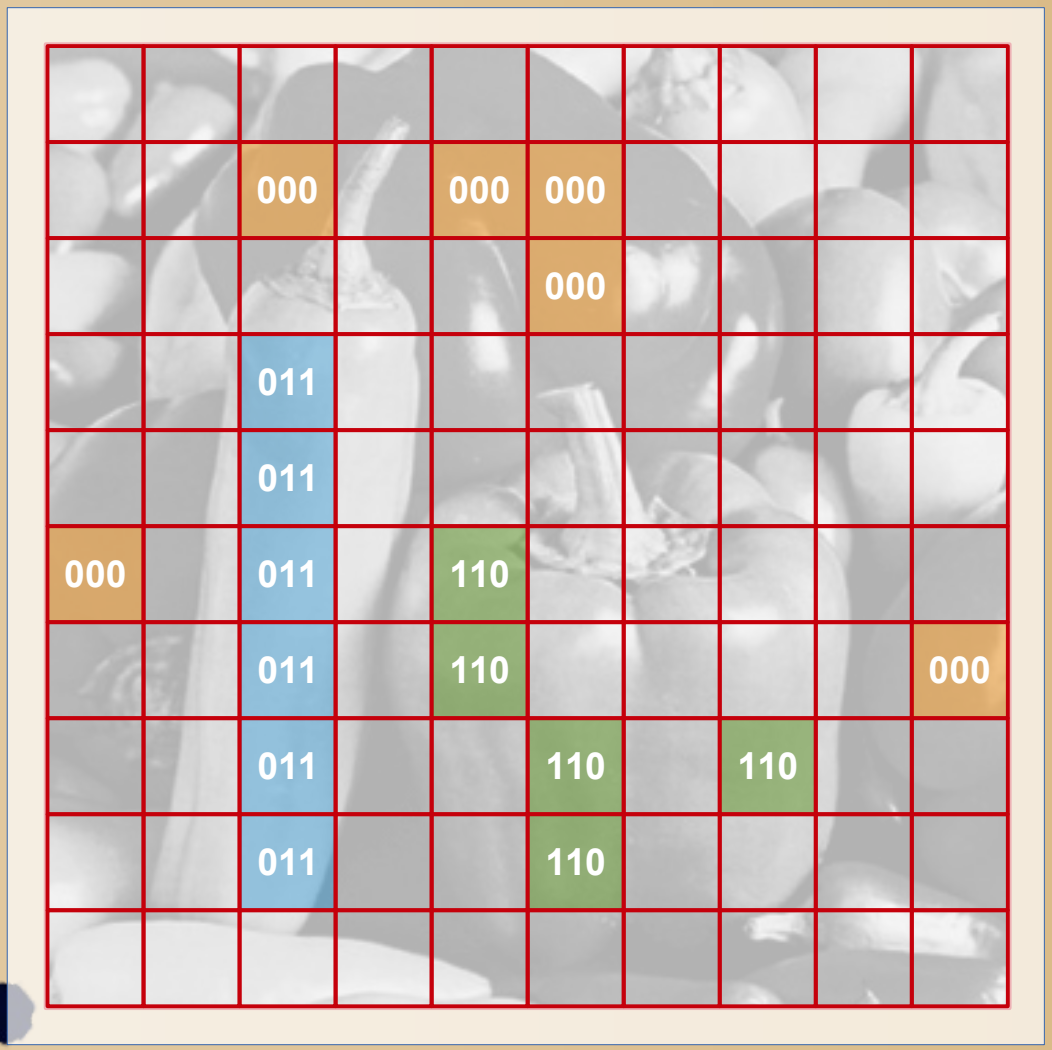

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Substitute Each LABEL with Corresponding Vector in the Codebook

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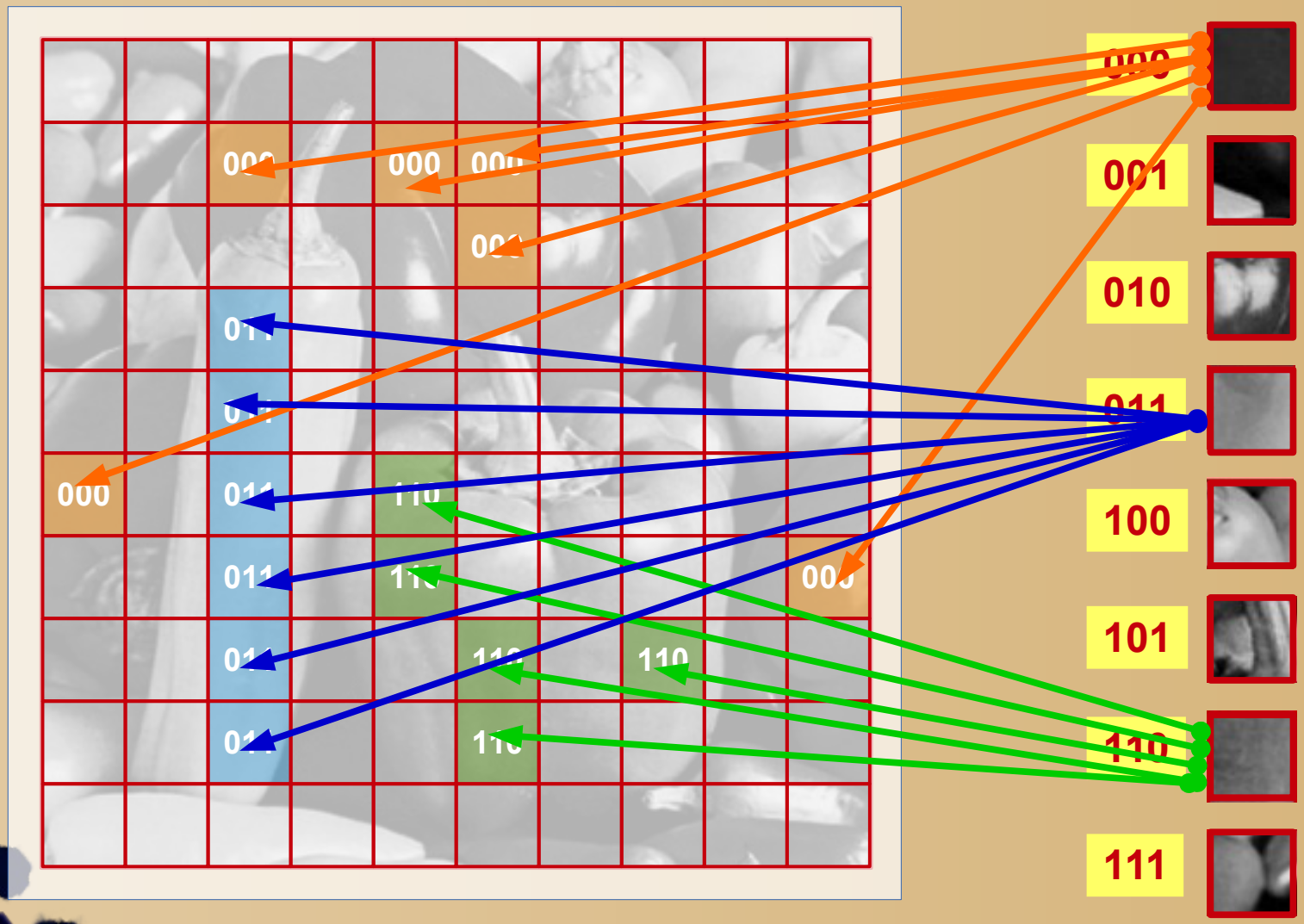

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Obtained Constructed Image

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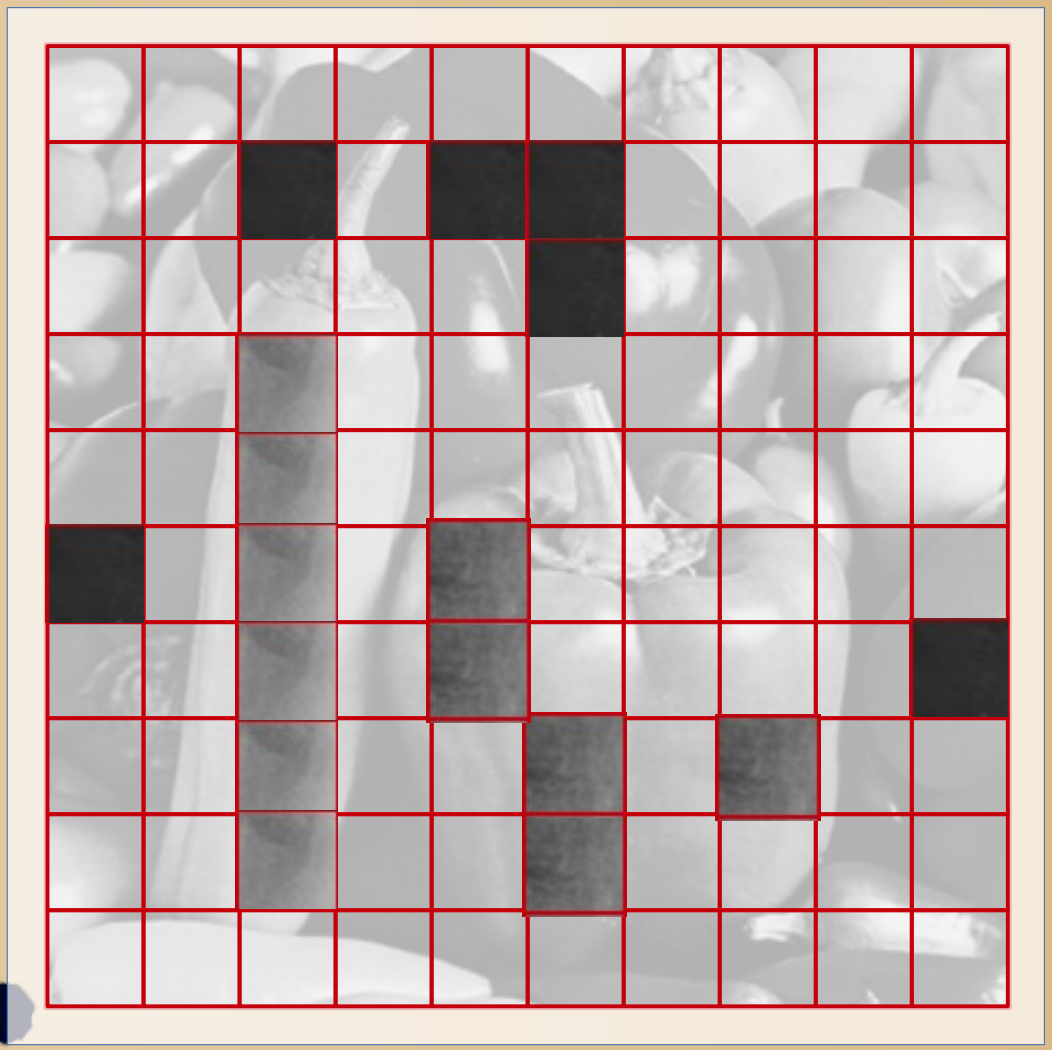
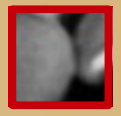


000	
001	
010	
011	
100	
101	
110	
111	

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Vector Quantization Samples

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Original

Blocking Effect

Vector Size is Large

Number of Vectors in codebook is small

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Vector Quantization using Splitting (Example)

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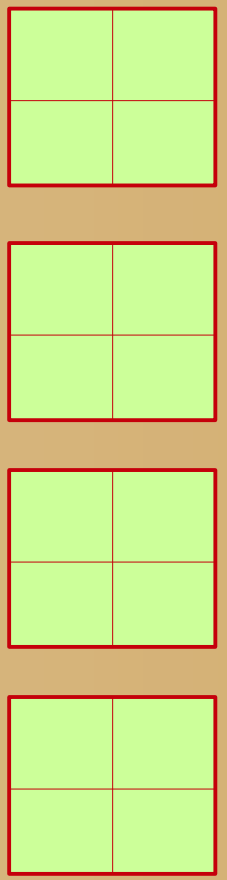
Compress the following Image Using Vector Quantization (initialize LBG Algorithm using Splitting)
(Each pixel is saved in 8 bits)

Vector size = 2*2
Number of Vectors in Codebook = 4

1	2	7	9	4	11
3	4	6	6	12	12
4	9	15	14	9	9
10	10	20	18	8	8
4	3	17	16	1	4
4	5	18	18	5	6



Reconstruct the Compressed Image,
Calculate Mean Square error between Original and Reconstructed Image
Calculate Compression Ratio
Re-Calculate Compression Ratio if the image is 600*600 pixels

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Vector Quantization using Splitting (Apply Splitting)

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1	2	7	9	4	11
3	4	6	6	12	12
4	9	15	14	9	9
10	10	20	18	8	8
4	3	17	16	1	4
4	5	18	18	5	6

Average

62/9	77/9
86/9	87/9

=

6.9	8.5
9.5	9.7

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Vector Quantization using Splitting (Apply Splitting)

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1	2	7	9	4	11
3	4	6	6	12	12
4	9	15	14	9	9
10	10	20	18	8	8
4	3	17	16	1	4
4	5	18	18	5	6

6.9	8.5
9.5	9.7

Splitting

6	8
9	9

7	9
10	10

Nearest Vector

1	2	7	9	4	3
3	4	6	6	4	5
9	9	1	4		
8	8	5	6		

Equal Distance

4	11	4	9
12	12	10	10
15	14	17	16
20	18	18	18

Average

22/5	27/5	=	4.4	5.4		10	12
26/5	29/5		5.2	5.8		15	14.5

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Vector Quantization using Splitting (Apply Splitting)

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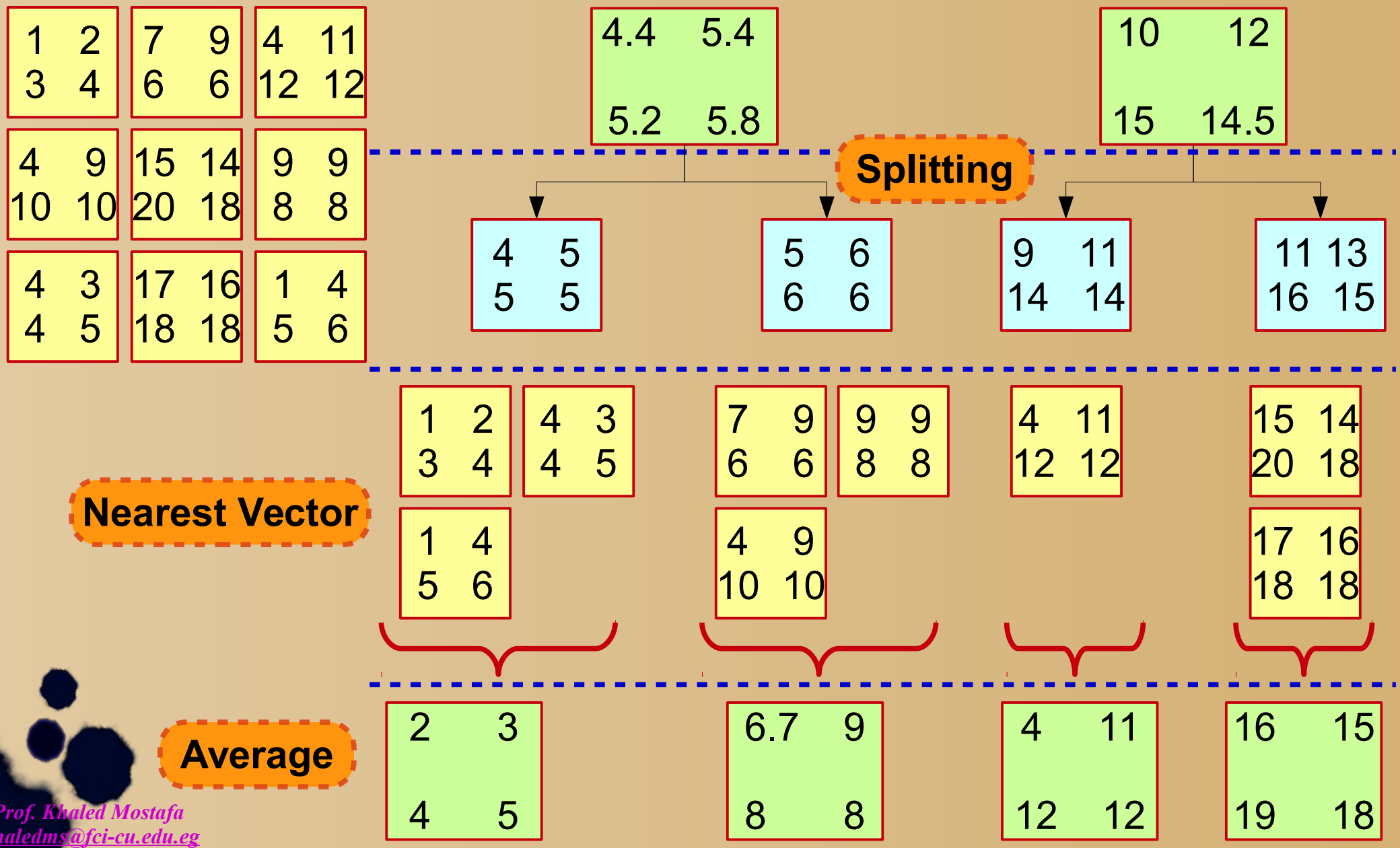

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Vector Quantization using Splitting (LBG Algorithm)

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1	2	7	9	4	11	2	3	6.7	9	4	11	16	15
3	4	6	6	12	12	4	5	8	8	12	12	19	18
4	9	15	14	9	9	1	2	9	9	4	11	15	14
10	10	20	18	8	8	3	4	8	8	12	12	20	18
4	3	17	16	1	4	1	4	7	9	4	9	17	16
4	5	18	18	5	6	5	6	6	6	10	10	18	18
						4	3						
						4	5						

Nearest Vector

Average

2	3	8	9	4	10	16	15
4	5	7	7	11	11	19	18

Changed

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Vector Quantization using Splitting (LBG Algorithm)

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1	2	7	9	4	11	2	3	8	9	4	10	16	15
3	4	6	6	12	12	4	5	7	7	11	11	19	18
4	9	15	14	9	9	1	2	9	9	4	11	15	14
10	10	20	18	8	8	3	4	8	8	12	12	20	18
4	3	17	16	1	4	1	4	7	9	4	9	17	16
4	5	18	18	5	6	5	6	6	6	10	10	18	18
						4	3						
						4	5						

Nearest Vector

Average

2	3	8	9	4	10	16	15
4	5	7	7	11	11	19	18

No Change (Stop Iteration)

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Image Encoding

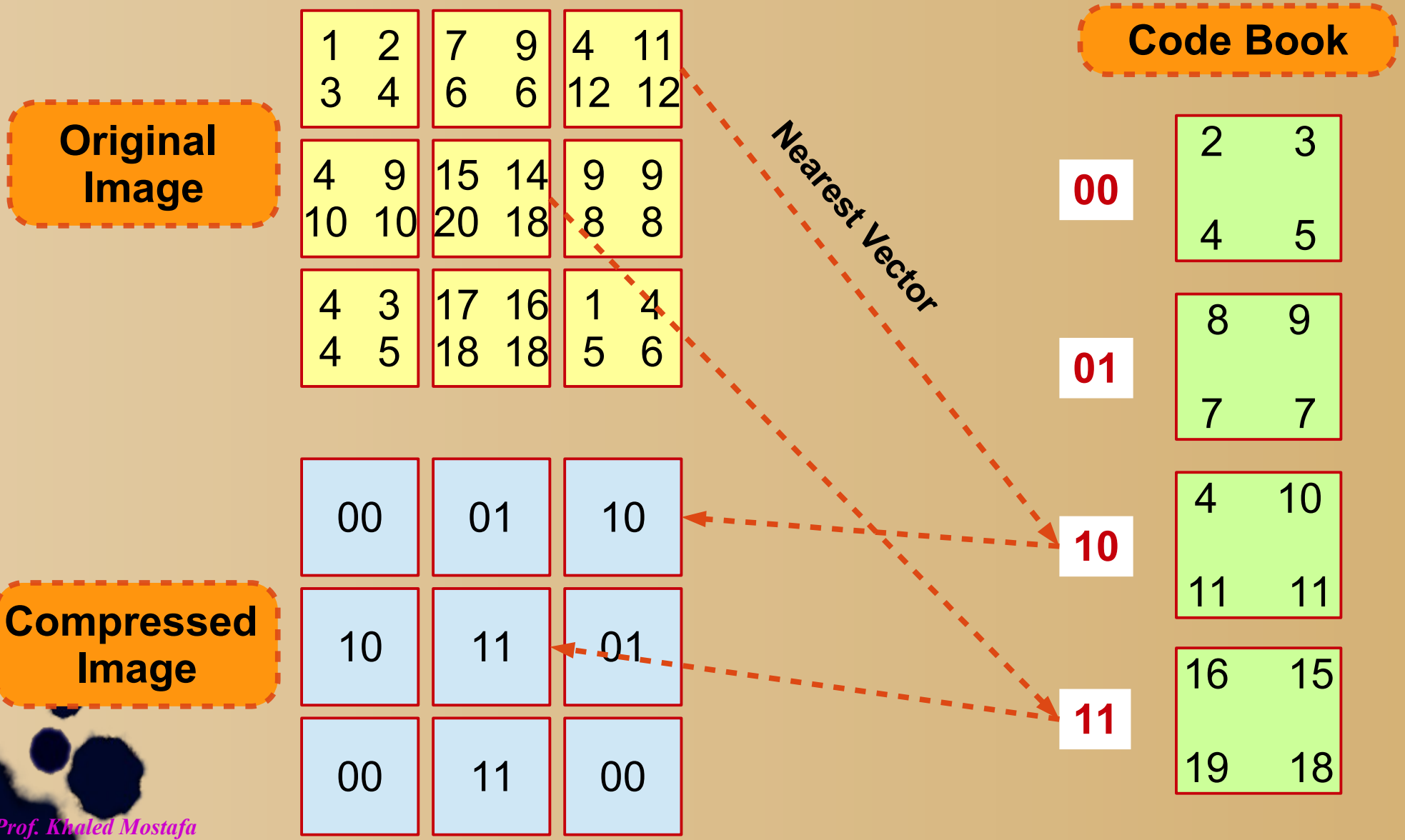

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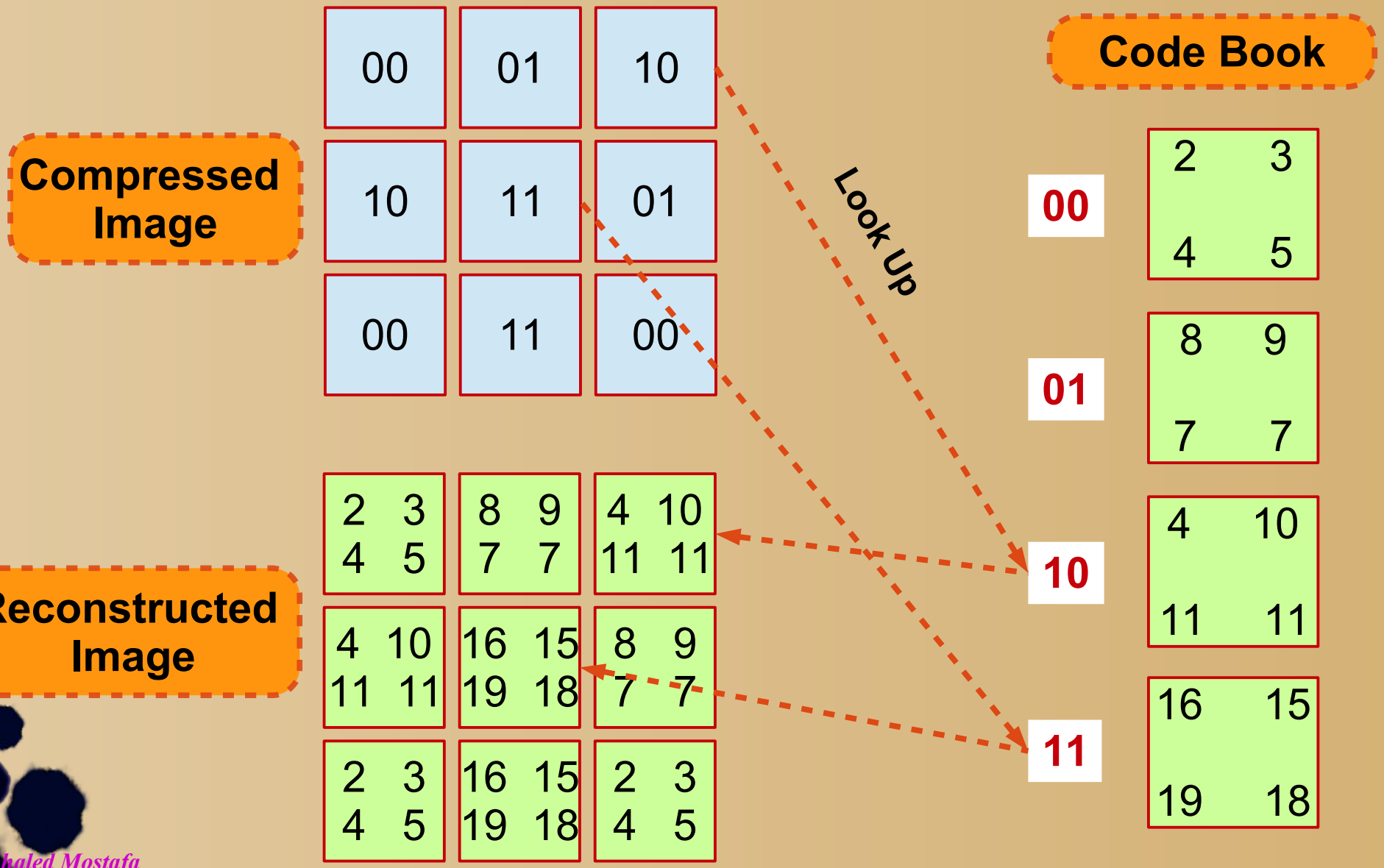
Image Decoding



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Mean Squared Error

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Original Image			Reconstructed Image			Squared Error		
1 2 3 4	7 9 6 6	4 11 12 12	2 3 4 5	8 9 7 7	4 10 11 11	1 1 1 1	1 0 1 1	0 1 1 1
4 9 10 10	15 14 20 18	9 9 8 8	4 10 11 11	16 15 19 18	8 9 7 7	0 1 1 1	1 1 1 0	1 0 1 1
4 3 4 5	17 16 18 18	1 4 5 6	2 3 4 5	16 15 19 18	2 3 4 5	4 0 0 0	1 1 1 0	1 1 1 1

Mean Squared Error = 30/36 = 0.833

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Compression Ratio

- **Original Image Size**=

  6*6 (pixels) * 8 bits/pixel = 6x6x8= 288 bits

- **Number of Blocks** (vectors) in Image =

  (6*6)/ (2*2)=36/4 = 9 blocks

- Each Block is substituted by 2 Bits Label
- **Labels size** = 9 blocks * 2 bits = 18 bits
- **Codebook size** =

  4 Vectors * (2*2) pixels/vector * 8 bits/pixel = 4*2*2*8=128 bits

- **Total Compressed size** = Codebook +Labels = 128 + 18 = 146 bits
- **Compression Ratio** = 288/146 = 1.97:1

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Compression Ratio

- **Original Image Size**=

  600*600 (pixels) * 8 bits/pixel = 6x6x8= 2,880,000 bits

- **Number of Blocks** (vectors) in Image =

  (600*600)/ (2*2)=360000/4 = 90,000 blocks

- Each Block is substituted by 2 Bit Label
- **Labels size** = 90,000 blocks * 2 bits = 180,000 bits
- **Codebook size** = 128 bits (as before)
- **Total Compressed size** = 128 + 180,000 =~ 180,000 bits
- **Compression Ratio** = 2,880,000/180,000 = 16:1

(each **4 pixels** = 32 bits are substituted with **2 bits label**)

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