Lecture 05 – Intensity transformations II

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joaof.mari@ufv.br

Agenda

- Histogram equalization

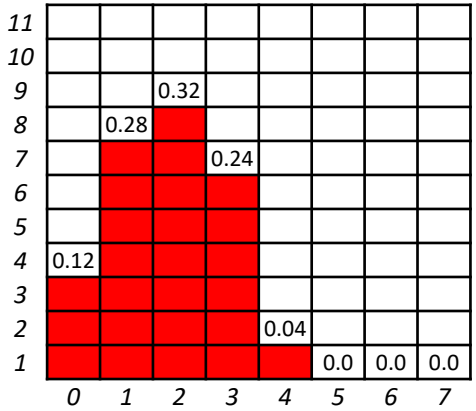
Histogram equalization

Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
4	0	0	1	1	1

5 x 5 pixels = 25 pixels
3 bits or 2^3 = 8 gray levels (L).
Gray level range: [0, 7]

Normalized histogram



Histogram equalization

Original image

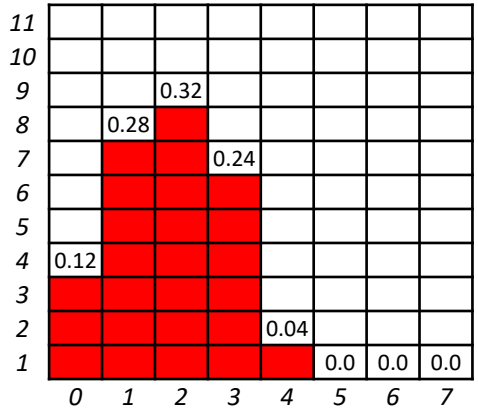
	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
4	0	0	1	1	1

5 x 5 pixels = 25 pixels
3 bits or 2^3 = 8 gray levels (L).
Gray level range: [0, 7]

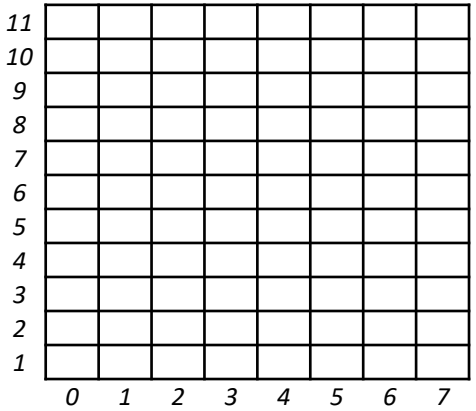
Processed image

	0	1	2	3	4
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0

Normalized histogram



Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
4	0	0	1	1	1

5 x 5 pixels = 25 pixels
3 bits or 2^3 = 8 gray levels (L).
Gray level range: [0, 7]

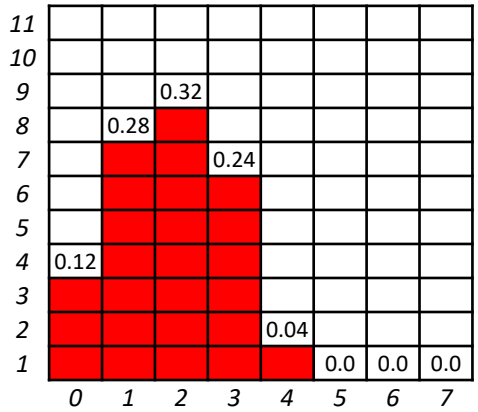
$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

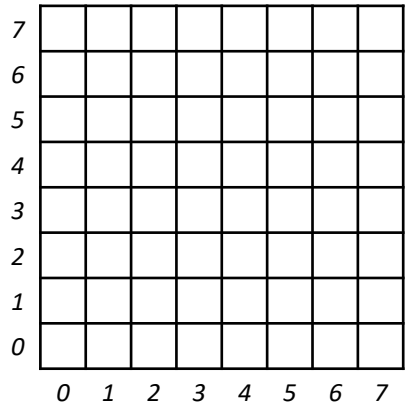
k	p'	$s_k=T(r_k)$
0		
1		
2		
3		
4		
5		
6		
7		

Processed image

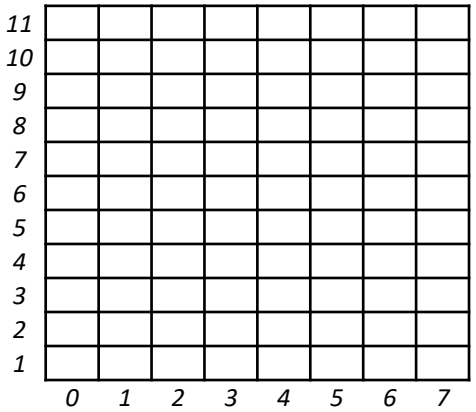
	0	1	2	3	4
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

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Gray level range: [0, 7]

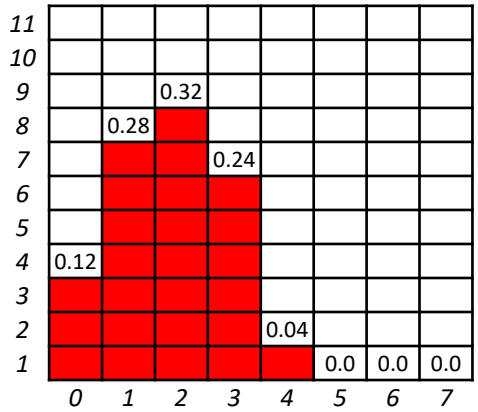
$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

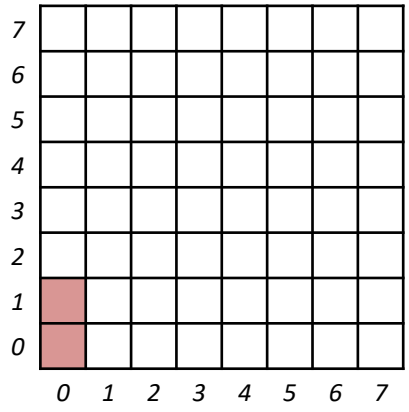
k		p'	$s_k=T(r_k)$
0	7 × (0.12)	= 0.84	= 1
1			
2			
3			
4			
5			
6			
7			

Processed image

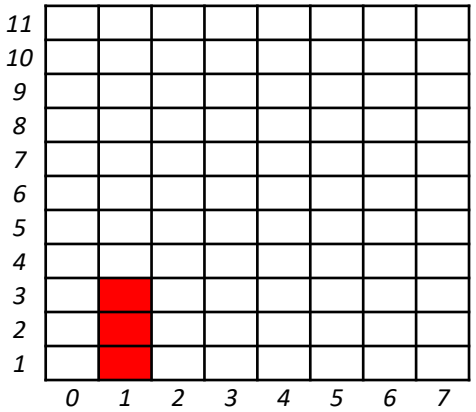
	0	1	2	3	4
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	1	0	0	0	0
4	1	1	0	0	0

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

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Gray level range: [0, 7]

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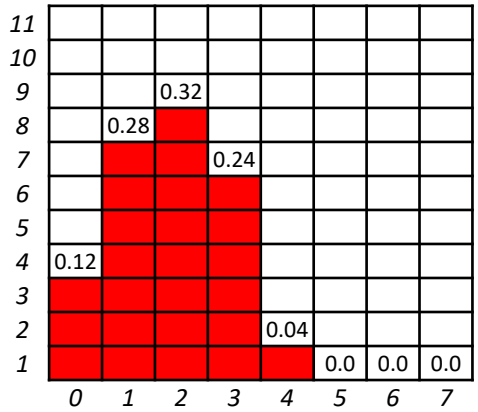
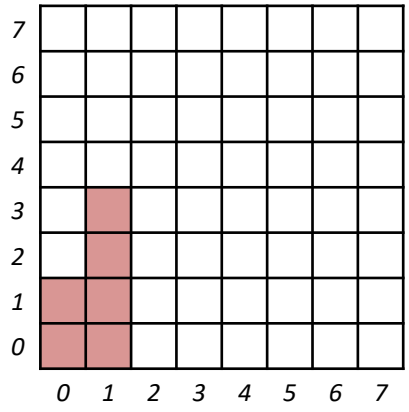
k		p'	s_k=T(r_k)
0	7 × (0.12)	= 0.84	= 1
1	7 × (0.12 + 0.28)	= 2.80	= 3
2			
3			
4			
5			
6			
7			

Processed image

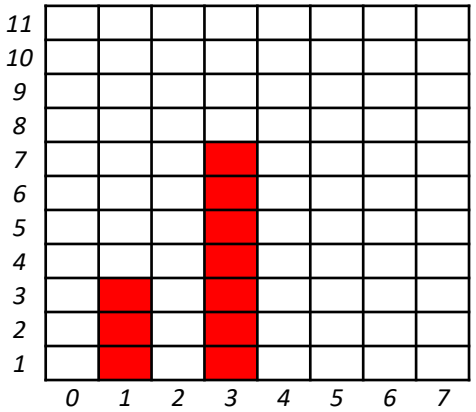
	0	1	2	3	4
0	3	0	0	0	3
1	3	0	0	0	0
2	3	0	0	0	0
3	1	0	0	0	0
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
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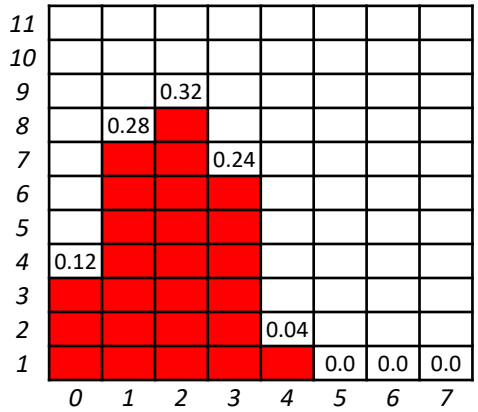
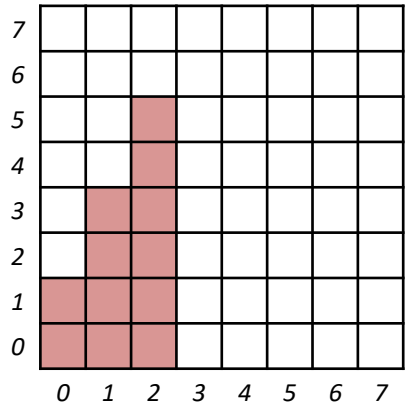
k		p'	$s_k=T(r_k)$
0	7 × (0.12)	= 0.84	= 1
1	7 × (0.12 + 0.28)	= 2.80	= 3
2	7 × (0.12 + 0.28 + 0.32)	= 5.04	= 5
3			
4			
5			
6			
7			

Processed image

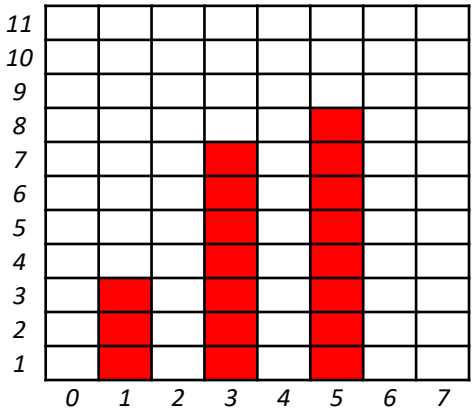
	0	1	2	3	4
0	3	5	5	0	3
1	3	0	0	0	5
2	3	5	0	0	5
3	1	5	5	0	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
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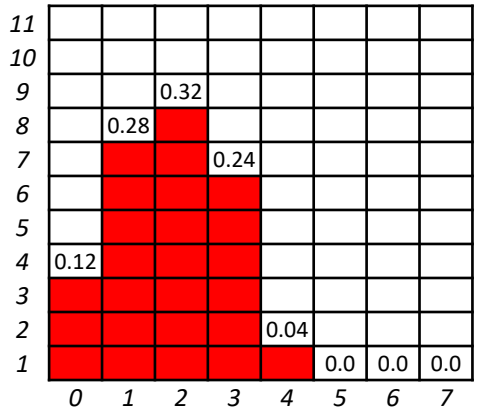
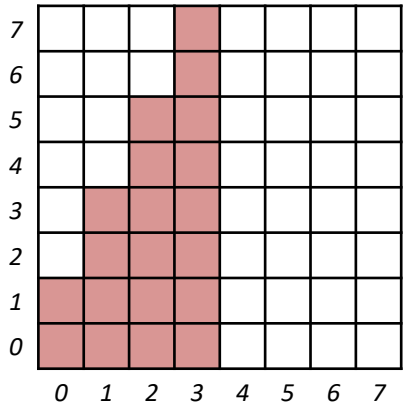
1	7 × (0.12 + 0.28)	= 2.80	= 3
2	7 × (0.12 + 0.28 + 0.32)	= 5.04	= 5
3	7 × (0.12 + 0.28 + 0.32 + 0.24)	= 6.72	= 7
4			
5			
6			
7			

Processed image

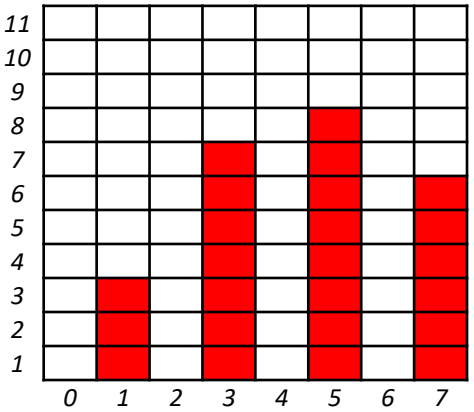
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	0	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
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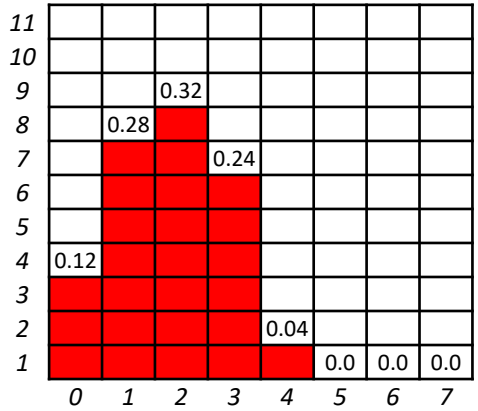
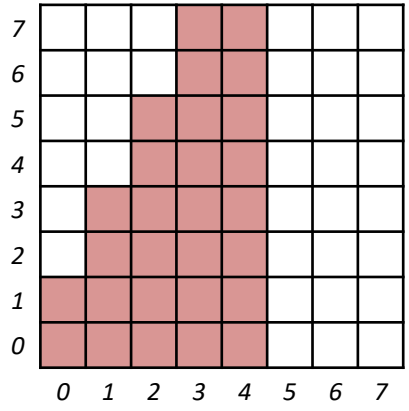
2	7 × (0.12 + 0.28 + 0.32)	= 5.04	= 5
3	7 × (0.12 + 0.28 + 0.32 + 0.24)	= 6.72	= 7
4	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04)	= 7.00	= 7
5			
6			
7			

Processed image

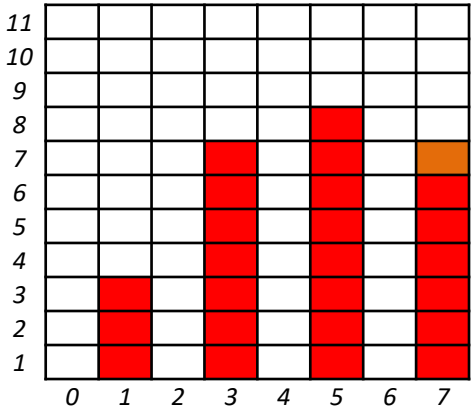
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	7	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
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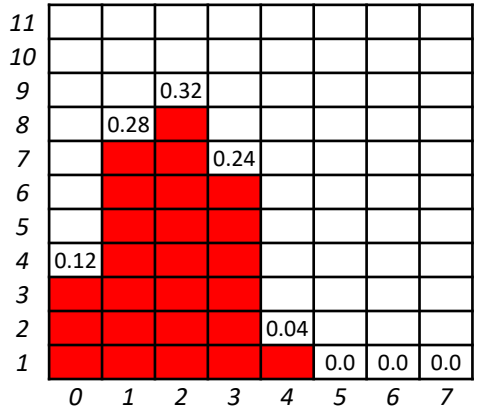
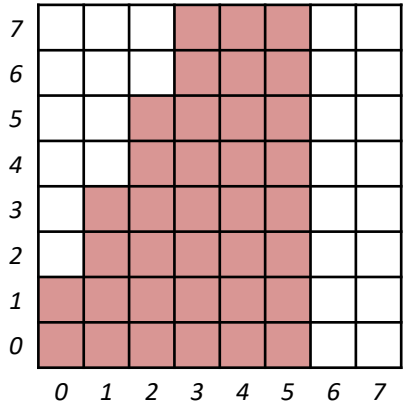
3	7 × (0.12 + 0.28 + 0.32 + 0.24)	= 6.72	= 7
4	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04)	= 7.00	= 7
5	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0)	= 7.00	= 7
6			
7			

Processed image

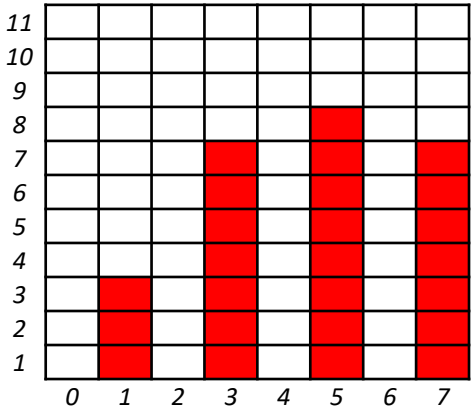
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	7	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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	0	1	2	3	4
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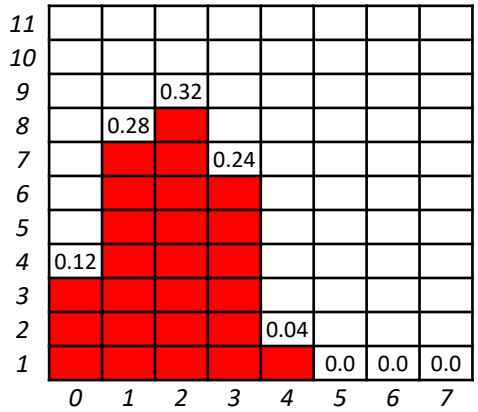
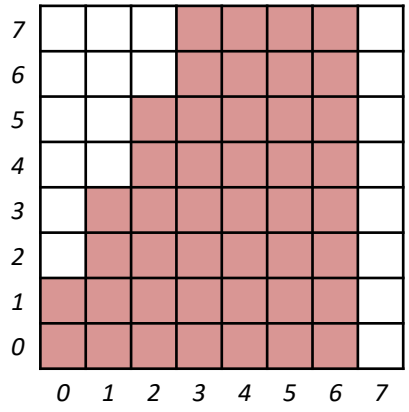
4	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04)	= 7.00	= 7
5	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0)	= 7.00	= 7
6	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0 + 0)	= 7.00	= 7
7			

Processed image

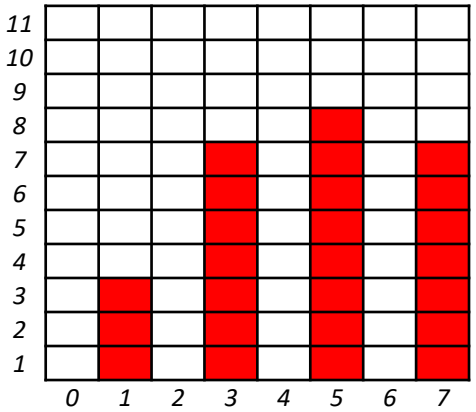
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	7	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

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Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
4	0	0	1	1	1

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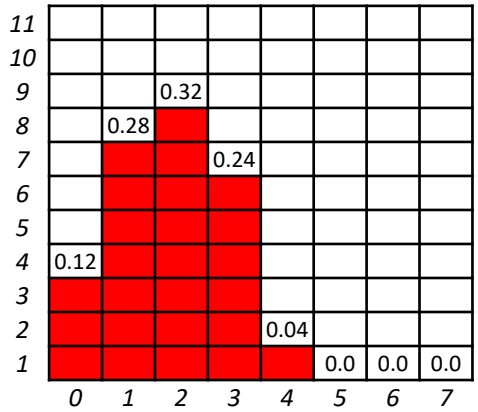
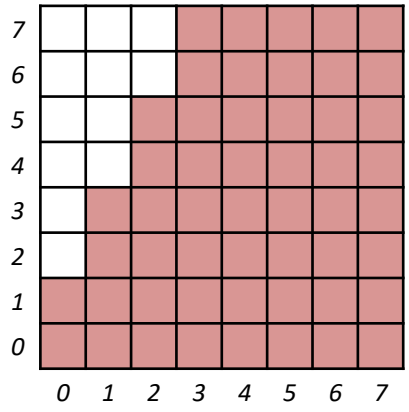
3	7 × (0.12 + 0.28 + 0.32 + 0.24)	= 6.72	= 7
4	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04)	= 7.00	= 7
5	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0)	= 7.00	= 7
6	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0 + 0)	= 7.00	= 7
7	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0 + 0)	= 7.00	= 7

Processed image

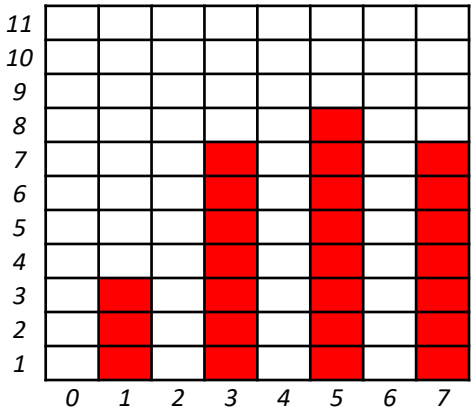
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	7	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Histogram equalization

UFV
Universidade Federal de Viçosa

Original image

	0	1	2	3	4
0	1	2	2	3	1
1	1	3	3	4	2
2	1	2	3	3	2
3	0	2	2	3	2
4	0	0	1	1	1

5 x 5 pixels = 25 pixels
3 bits or 2^3 = 8 gray levels (L).
Gray level range: [0, 7]

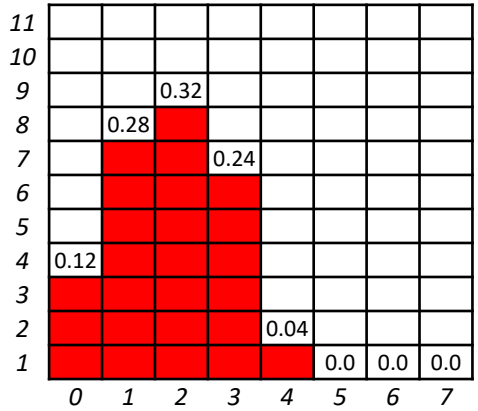
$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

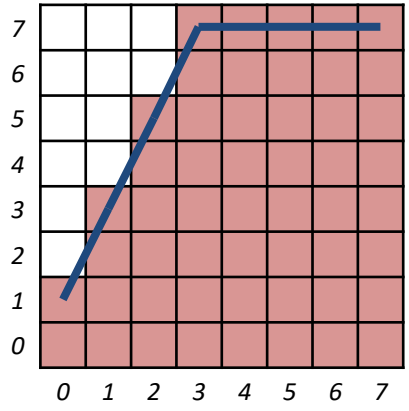
k		p'	$s_k=T(r_k)$
0	7 × (0.12)	= 0.84	= 1
1	7 × (0.12 + 0.28)	= 2.80	= 3
2	7 × (0.12 + 0.28 + 0.32)	= 5.04	= 5
3	7 × (0.12 + 0.28 + 0.32 + 0.24)	= 6.72	= 7
4	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04)	= 7.00	= 7
5	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0)	= 7.00	= 7
6	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0 + 0)	= 7.00	= 7
7	7 × (0.12 + 0.28 + 0.32 + 0.24 + 0.04 + 0 + 0)	= 7.00	= 7

Processed image

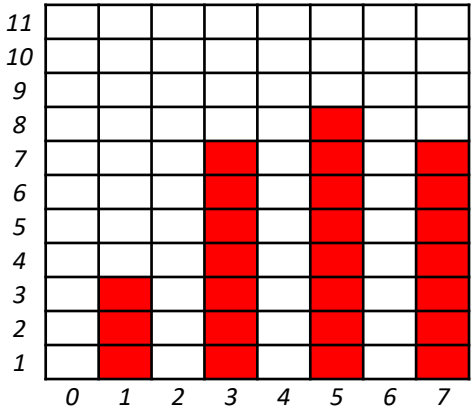
	0	1	2	3	4
0	3	5	5	7	3
1	3	7	7	7	5
2	3	5	7	7	5
3	1	5	5	7	5
4	1	1	3	3	3

Normalized histogram





Normalized histogram



Bibliography

- GONZALEZ, R.C.; WOODS, R.E. **Digital Image Processing**. 3rd ed. Pearson, 2007.
  - Sections 3.1 until 3.2.3

- MARQUES FILHO, O.; VIEIRA NETO, H. **Processamento digital de imagens**. Brasport, 1999.
  - (*in Brazilian Portuguese*)
  - Available on the author's website (for personal use only)
  - http://dainf.ct.utfpr.edu.br/~hvieir/pub.html
  - Sections 3.1 and 3.2

- J. E. R. Queiroz, H. M. Gomes. **Introdução ao Processamento Digital de Imagens**. RITA. v. 13, 2006.
  - (*in Brazilian Portuguese*)
  - http://www.dsc.ufcg.edu.br/~hmg/disciplinas/graduacao/vc-2016.2/Rita-Tutorial-PDI.pdf
  - Section 3

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@misc{mari_im_proc_2023,
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THE END