COMP 478 - Image Processing

Assignment 01

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1. a) In order to get a flat histogram, you would need an image with *L* groups of *L* pixels having the same intensity, which is usually not the case with an input image which is why usually no new intensity levels are created since the input (r_n) and output ($L-1 * p(s_n)$) intensities are going to be similar. The technique does flatten them a little, resulting in image with an enhanced contrast, but not completely for the aforementioned reasons.

b) The discrete histogram equalization technique produces a *uniformly distributed* image. Therefore, re-running this technique does not yield a flat histogram – the resulting image would be relatively unchanged.

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2. No. H [af(x, y) + bg(x, y)] != aH [f(x, y)] + bH [g(x, y)] for an operator that computes the median of a set of pixels of a sub-image area.

Consider an example where:

1. a = b = 1
2. f(x, y) = {1, 2, 3} => aH [f(x, y)] = median of {1, 2, 3} = 2
3. g(x, y) = {1, -2, 3} => bH [g(x, y)] = median of {1, -2, 3} = 1

Therefore,
LHS = H [af(x, y) + bg(x, y)] = H [{1, 2, 3} + {1, -2, 3}] = median of {2, 0, 6} = 2
RHS = aH [f(x, y)] + bH [g(x, y)] = 2 + 1 = 3

LHS != RHS => QED

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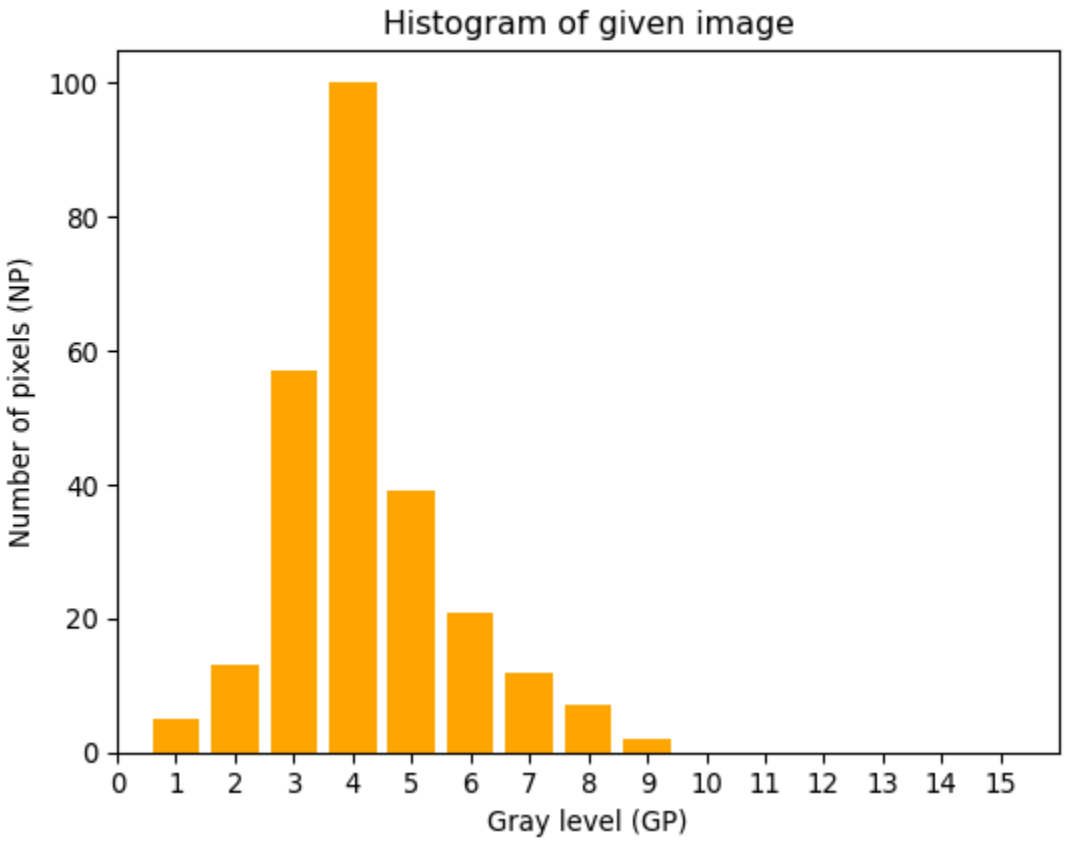
3. a)



b) i) n = 256 since that is the sum of all n_k (image size)

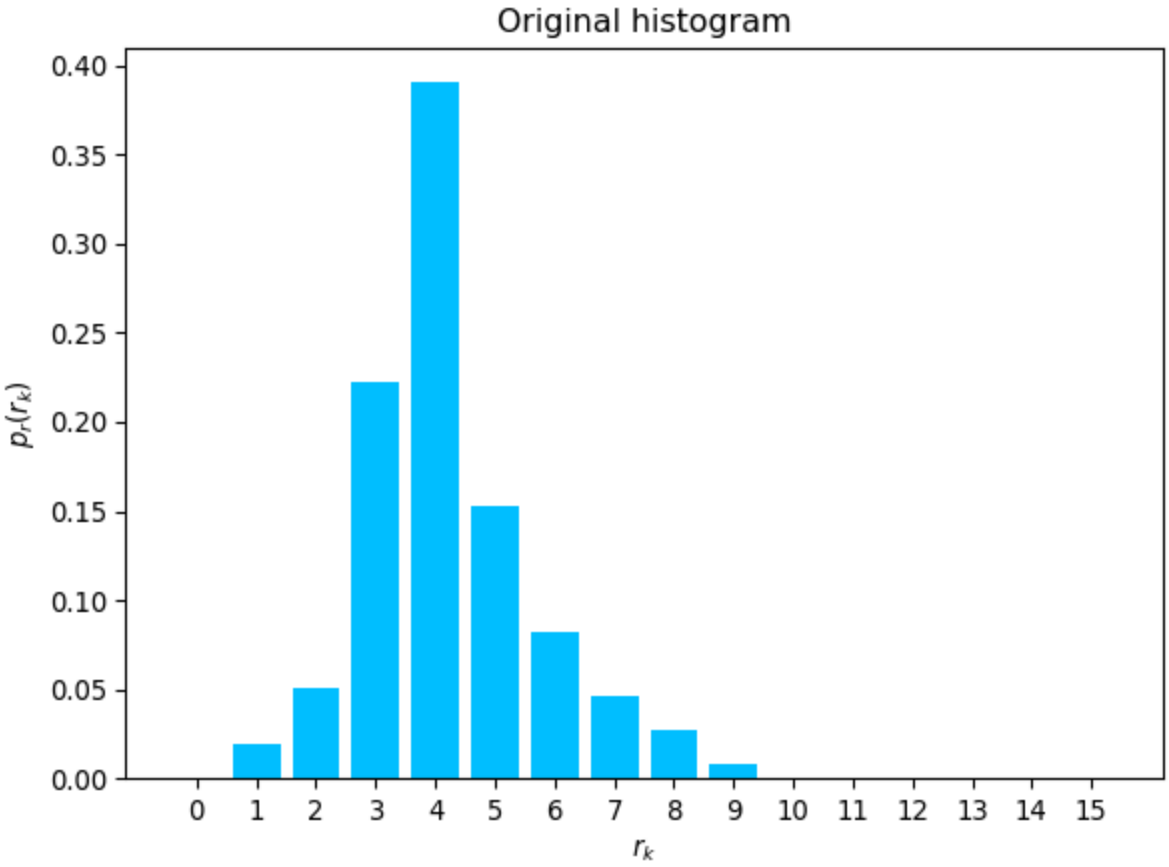
L = 16 since it is a 4 bit image (intensity)

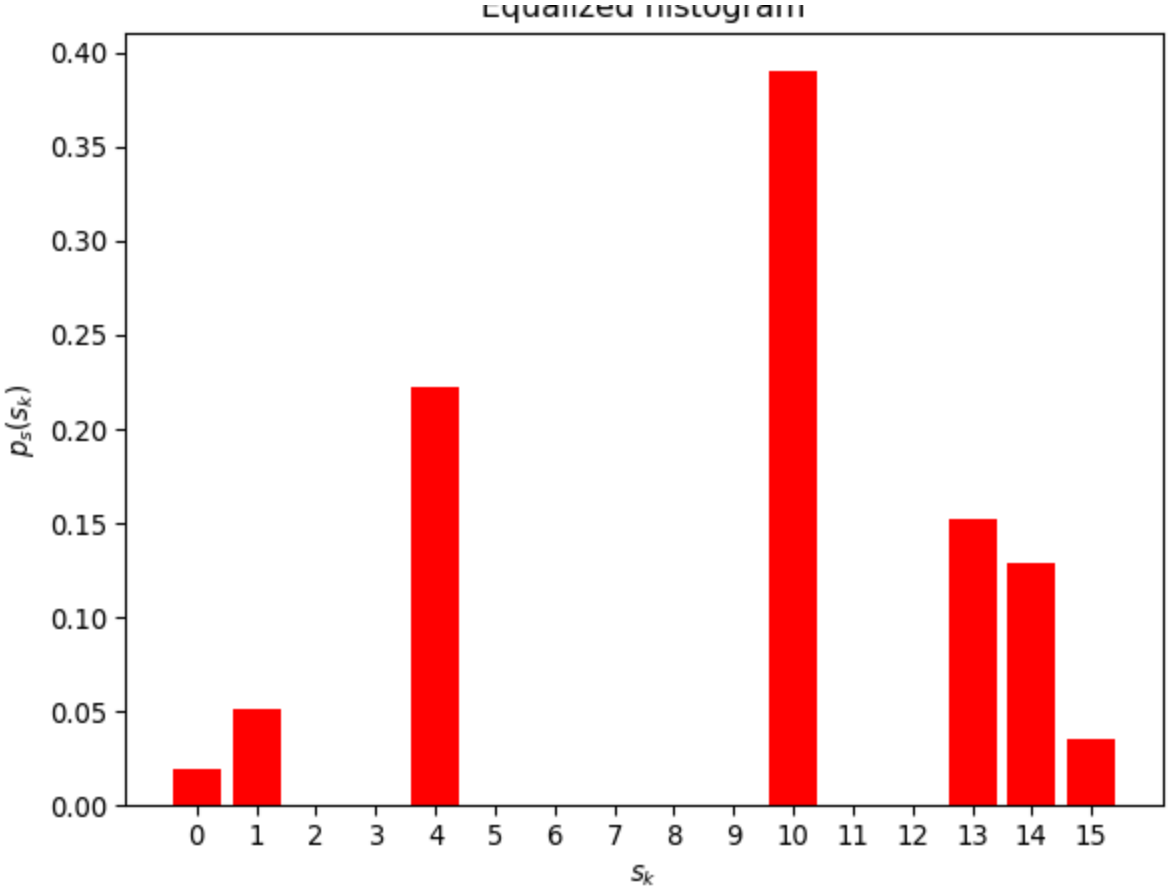
r_k	n_k	$p_r(r_k)$	s_k
0	0	0/256 = 0	0
1	5	5/256 = 0.01953125	0
2	13	13/256 = 0.05078125	1
3	57	57/256 = 0.22265625	4
4	100	100/256 = 0.390625	10
5	39	39/256 = 0.15234375	13
6	21	21/256 = 0.08203125	14

r_k	n_k	$p_r(r_k)$	s_k
7	12	12/256 = 0.046875	14
8	7	7/256 = 0.02734375	15
9	2	2/256 = 0.0078125	15
10	0	0/256 = 0	15
11	0	0/256 = 0	15
12	0	0/256 = 0	15
13	0	0/256 = 0	15
14	0	0/256 = 0	15
15	0	0/256 = 0	15

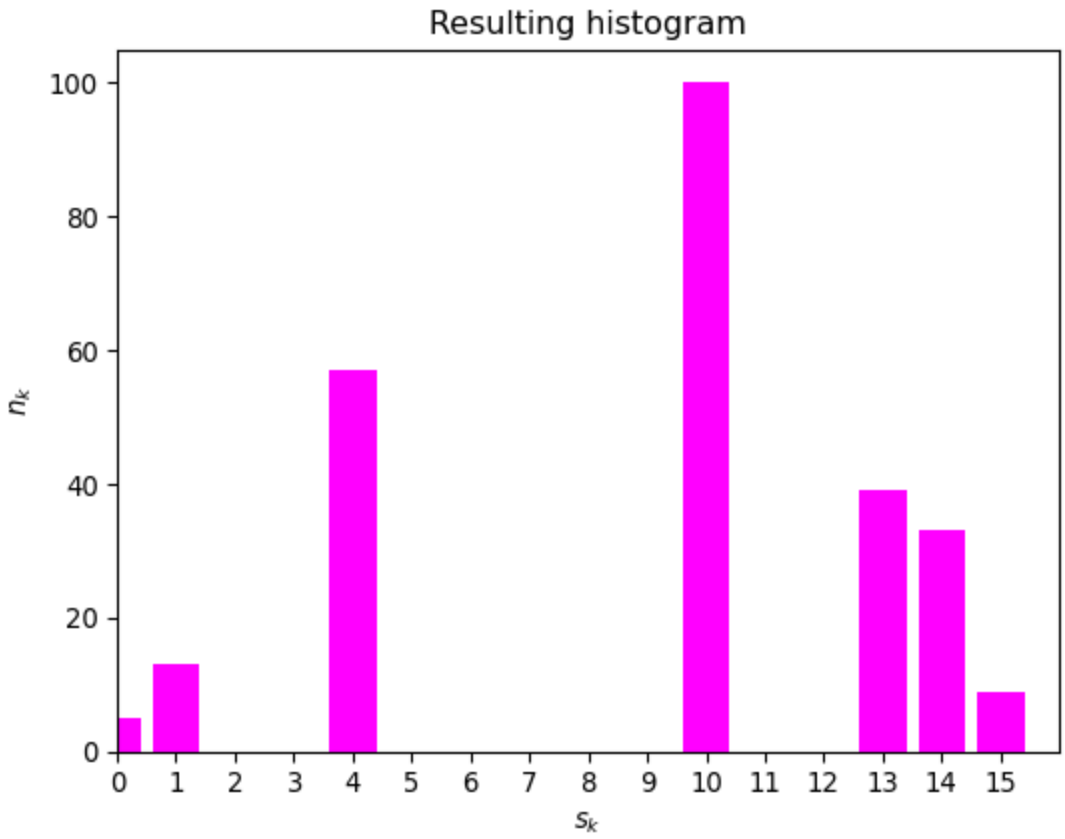
ii)

s_k	n_k	$p_s(s_k)$
0	5	5/256 = 0.01953125
1	13	13/256 = 0.05078125
4	57	57/256 = 0.22265625
10	100	100/256 = 0.390625
13	39	39/256 = 0.15234375
14	33	33/256 = 0.12890625
15	9	9/256 = 0.03515625


Original histogram
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
$p_r(r_k)$
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
r_k


Equalized histogram
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
$p_s(s_k)$
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
s_k

c)



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4. For f(x, y) + g(x, y)

Theory Assignment code used to generate all histograms:

```python
import matplotlib.pyplot as plt
import numpy as np


def function_3a():
    x = np.arange(16)
    y = np.array([0, 5, 13, 57, 100, 39, 21, 12, 7, 2, 0, 0, 0, 0, 0, 0])

    plt.bar(x, y, color="orange")

    plt.xlabel("Gray level (GP)")
    plt.ylabel("Number of pixels (NP)")

    plt.gca().set_xlim([0, 16])

    plt.title("Histogram of given image")
    plt.xticks(np.arange(0, 16, 1.0))

    plt.savefig("img/Figure_3a.png", dpi=95)
    plt.show()


def function_3bii():
    p_rk_x = np.arange(16)
    p_rk_y = np.array(
        [
            0,
            0.01953125,
            0.05078125,
            0.22265625,
            0.390625,
            0.15234375,
            0.08203125,
            0.046875,
            0.02734375,
            0.0078125,
            0,
            0,
            0,
            0,
            0,
            0,
        ]
    )

    p_sk_x = np.array([0, 1, 4, 10, 13, 14, 15])
```

```
    p_sk_y = np.array(
        [
            0.01953125,
            0.05078125,
            0.22265625,
            0.390625,
            0.15234375,
            0.12890625,
            0.03515625,
        ]
    )

    plt.bar(p_rk_x, p_rk_y, color="deepskyblue")
    plt.xlabel("$r_k$")
    plt.ylabel("$p_r(r_k)$")
    plt.title("Original histogram")
    plt.xticks(np.arange(0, 16, 1.0))
    plt.tight_layout()
    plt.savefig("img/Figure_3bii1.png", dpi=95)
    plt.show()

    plt.bar(p_sk_x, p_sk_y, color="red")
    plt.xlabel("$s_k$")
    plt.ylabel("$p_s(s_k)$")
    plt.xticks(np.arange(0, 16, 1.0))
    plt.tight_layout()
    plt.title("Equalized histogram")
    plt.savefig("img/Figure_3bii2.png", dpi=95)
    plt.show()


def function_3c():
    s_k_x = np.array([0, 1, 4, 10, 13, 14, 15])
    n_k_y = np.array([5, 13, 57, 100, 39, 33, 9])

    plt.bar(s_k_x, n_k_y, color="magenta")

    plt.xlabel("$s_k$")
    plt.ylabel("$n_k$")

    plt.gca().set_xlim([0, 16])

    plt.title("Resulting histogram")
    plt.xticks(np.arange(0, 16, 1.0))

    plt.savefig("img/Figure_3c.png", dpi=95)
```

```
    plt.show()


if __name__ == "__main__":
    function_3a()
    function_3bii()
    function_3c()
```