ECE 253 Homework 1

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Problem 1. Basics

In [1]:
```
import numpy as np

A = np.array([[3, 9, 5, 1], [4, 25, 4, 3], [63, 13, 23, 9], [6, 32, 77, 0], [12, 8, 6, 1]])
B = np.array([[0, 1, 0, 1], [0, 1, 1, 0], [0, 0, 0, 1], [1, 1, 0, 1], [0, 1, 0, 0]])
```

In [2]:
```
# Problem (i)
C = np.multiply(A, B)
print('(i)')
print('Point-wise multiply A with B:')
print(C)
```

```
(i)
Point-wise multiply A with B:
[[ 0  9  0  1]
 [ 0 25  4  0]
 [ 0  0  0  9]
 [ 6 32  0  0]
 [ 0  8  0  0]]
```

In [3]:
```
# Problem (ii)
print('(ii)')
print('The inner product of the 2nd and 3rd row of C:')
print(np.dot(C[1], C[2]))
```

```
(ii)
The inner product of the 2nd and 3rd row of C:
0
```

In [4]:
```
# Problem (iii)
min_indices = np.where(C == np.min(C))
min_indices = np.concatenate((min_indices[0], min_indices[1]))
min_indices = min_indices.reshape((2,-1))
min_indices = min_indices.T

max_indices = np.where(C == np.max(C))
max_indices = np.concatenate((max_indices[0], max_indices[1]))
max_indices = max_indices.reshape((2,-1))
max_indices = max_indices.T

print('(iii)')
print('Minimum value in C:', np.min(C))
print('Maximum value in C:', np.max(C))
print('Indices of minimum value in C:')
print(min_indices)
print('Indices of axnimum value in C:')
print(max_indices)
```

```
(iii)
Minimum value in C: 0
Maximum value in C: 32
Indices of minimum value in C:
[[0 0]
 [0 2]
 [1 0]
 [1 3]
 [2 0]
 [2 1]
 [2 2]
 [3 2]
 [3 3]
 [4 0]
 [4 2]
 [4 3]]
Indices of axnimum value in C:
[[3 1]]
```

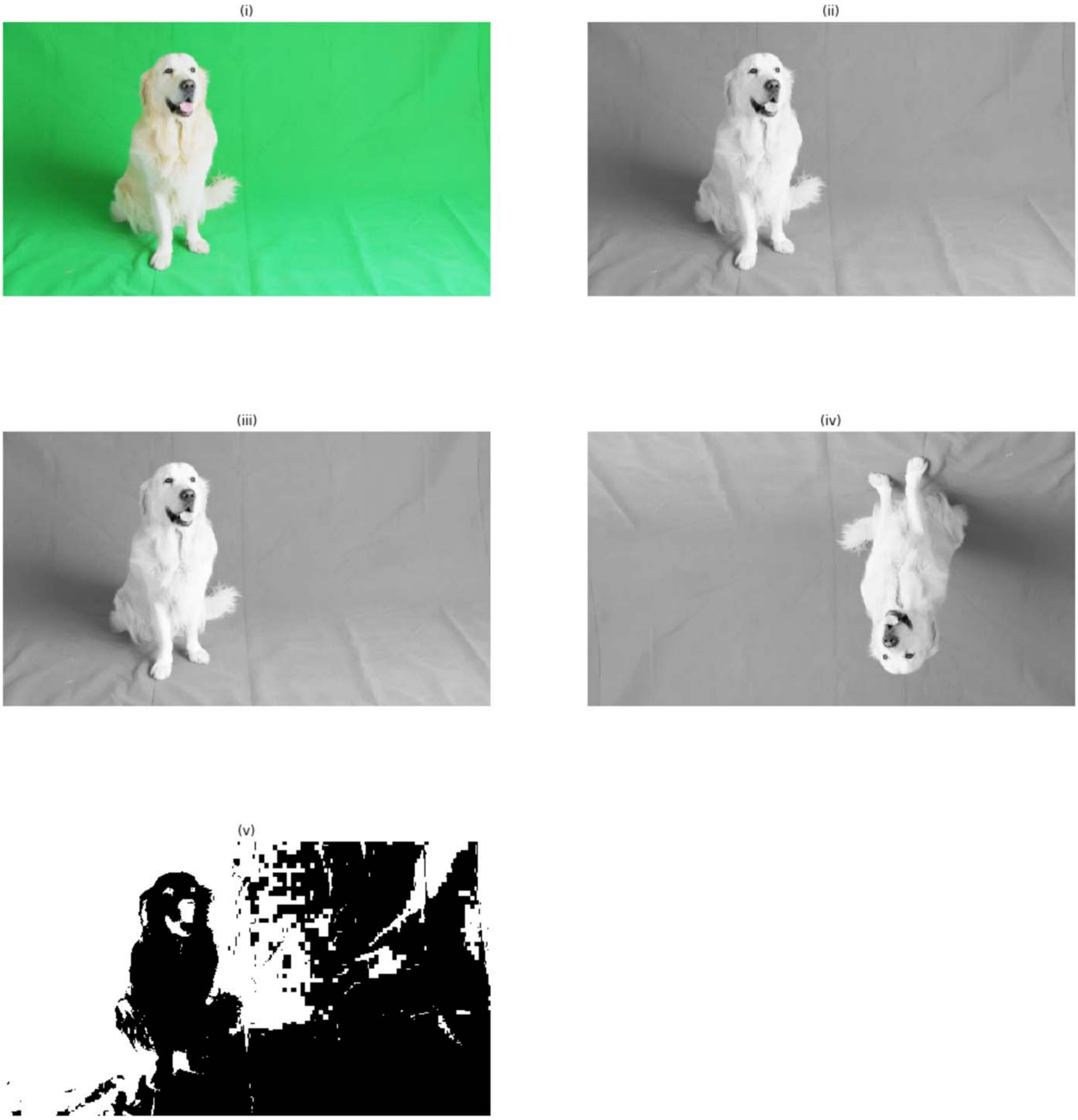
Problem 2. Simple image manipulation

In [5]:

```
import matplotlib.pyplot as plt
import copy

# Problem (i)
A = plt.imread('dog.jpg')

# Problem (ii)
r, g, b = A[:, :, 0], A[:, :, 1], A[:, :, 2]
B = 0.299 * r + 0.587 * g + 0.114 * b

# Problem (iii)
C = np.empty_like(B)
C[:] = B[:]+15
C[C > 255] = 255

# Problem (iv)
D = B[::-1, ::-1]

# Problem (v)
median = np.average(B)
E = copy.deepcopy(B)
E[E < median], E[E > median] = 0, 1
E = 1-E
```

In [6]:
```python
plt.figure(figsize=(18,20))
plt.subplot(3,2,1)
plt.title('(i)')
plt.axis('off')
plt.imshow(A)

plt.subplot(3,2,2)
plt.title('(ii)')
plt.axis('off')
plt.imshow(B, cmap='gray')

plt.subplot(3,2,3)
plt.title('(iii)')
plt.axis('off')
plt.imshow(C, cmap='gray')

plt.subplot(3,2,4)
plt.title('(iv)')
plt.axis('off')
plt.imshow(D, cmap='gray')

plt.subplot(3,2,5)
plt.title('(v)')
plt.axis('off')
plt.imshow(E, cmap='gray')
```

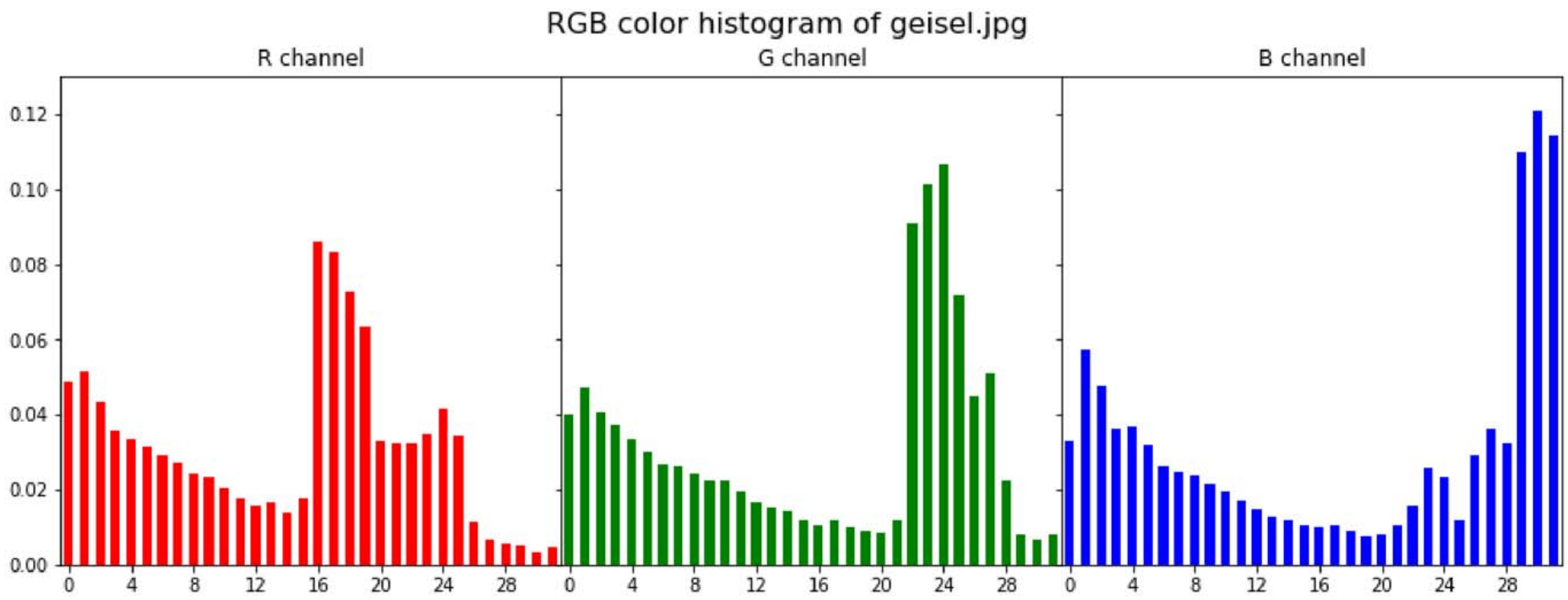
Out[6]: <matplotlib.image.AxesImage at 0x24f0e8d83c8>



Problem 3. Histograms

In [7]:
```python
def compute_norm_rgb_histogram(img):
    _, R = np.unique(A[:,:,0]//8, return_counts=True)
    _, G = np.unique(A[:,:,1]//8, return_counts=True)
    _, B = np.unique(A[:,:,2]//8, return_counts=True)

    H = np.concatenate((R,G,B))
    return H / (img.shape[0] * img.shape[1])
```

In [8]:
```python
A = plt.imread('geisel.jpg')
res = compute_norm_rgb_histogram(A)

fig, axs = plt.subplots(1, 3, sharey=True)
fig.set_size_inches((15,5))
fig.suptitle('RGB color histogram of geisel.jpg', fontsize=16)
fig.subplots_adjust(wspace=0) # Remove vertical space between axes

# Plot each graph
axs[0].bar(range(32), res[0:32], width=0.6, color='r')
axs[0].set_title('R channel')
axs[0].set_xticks(np.arange(0, 32, 4))
axs[0].set_yticks(np.arange(0, 0.13, 0.02))
axs[0].set_xlim(-0.5, 31.6)
axs[0].set_ylim(0, 0.13)

axs[1].bar(range(32), res[32:64], width=0.6, color='g')
axs[1].set_title('G channel')
axs[1].set_xticks(np.arange(0, 32, 4))
axs[1].set_yticks(np.arange(0, 0.13, 0.02))
axs[1].set_xlim(-0.5, 31.6)
axs[1].set_ylim(0, 0.13)

axs[2].bar(range(32), res[64:96], width=0.6, color='b')
axs[2].set_title('B channel')
axs[2].set_xticks(np.arange(0, 32, 4))
axs[2].set_yticks(np.arange(0, 0.13, 0.02))
axs[2].set_xlim(-0.5, 31.6)
axs[2].set_ylim(0, 0.13)

plt.show()
```



Problem 4. Chroma Keying

In [9]:
```
def foreground_man(img, background):
    mask = np.zeros_like(img)
    R = img[:,:,0]
    G = img[:,:,1]
    B = img[:,:,2]
    mask = (G < 100) | (R > G) | (B > G)
    binary = np.where(mask, 1, 0)

    foreground = np.zeros_like(img)
    zero = np.zeros_like(img)
    foreground[:,:,0] = np.where(mask, img[:,:,0], zero[:,:,0])
    foreground[:,:,1] = np.where(mask, img[:,:,2], zero[:,:,1])
    foreground[:,:,2] = np.where(mask, img[:,:,2], zero[:,:,2])

    comb = copy.deepcopy(background)
    h, w = img.shape[0], img.shape[1]
    x, y = 50, 48
    comb[y:y+h,x:x+w,0] = np.where(mask, img[:,:,0], comb[y:y+h,x:x+w,0])
    comb[y:y+h,x:x+w,1] = np.where(mask, img[:,:,2], comb[y:y+h,x:x+w,1])
    comb[y:y+h,x:x+w,2] = np.where(mask, img[:,:,2], comb[y:y+h,x:x+w,2])

    return binary, foreground, comb
```

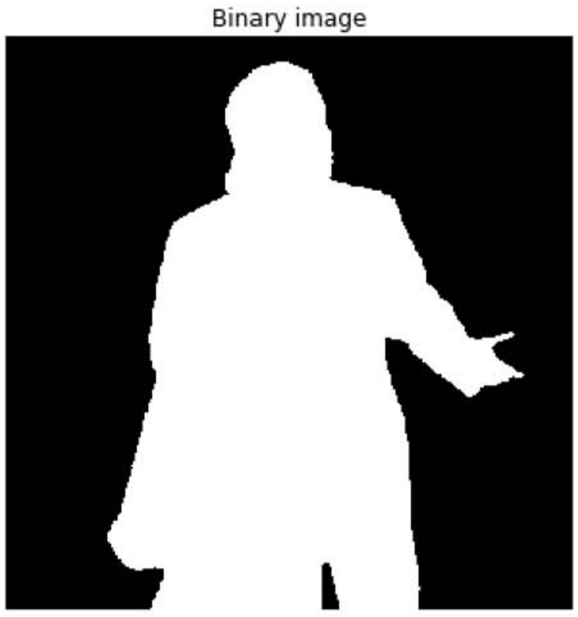
In [10]:

```python
man = plt.imread('travolta.jpg')
lib = plt.imread('library.jpg')
man_binary, man_fore, man_comb = foreground_man(man, lib)

plt.figure(figsize=(18,12))

plt.subplot(2,2,1)
plt.title('Original image')
plt.axis('off')
plt.imshow(man)

plt.subplot(2,2,2)
plt.title('Binary image')
plt.axis('off')
plt.imshow(man_binary, cmap='gray')

plt.subplot(2,2,3)
plt.title('Foreground')
plt.axis('off')
plt.imshow(man_fore)

plt.subplot(2,2,4)
plt.title('The foreground overlayed on a background of your choice')
plt.axis('off')
plt.imshow(man_comb)
```

Out[10]: <matplotlib.image.AxesImage at 0x24f0f5aceb8>

Original image

Binary image



Foreground

The foreground overlayed on a background of your choice

In [11]:

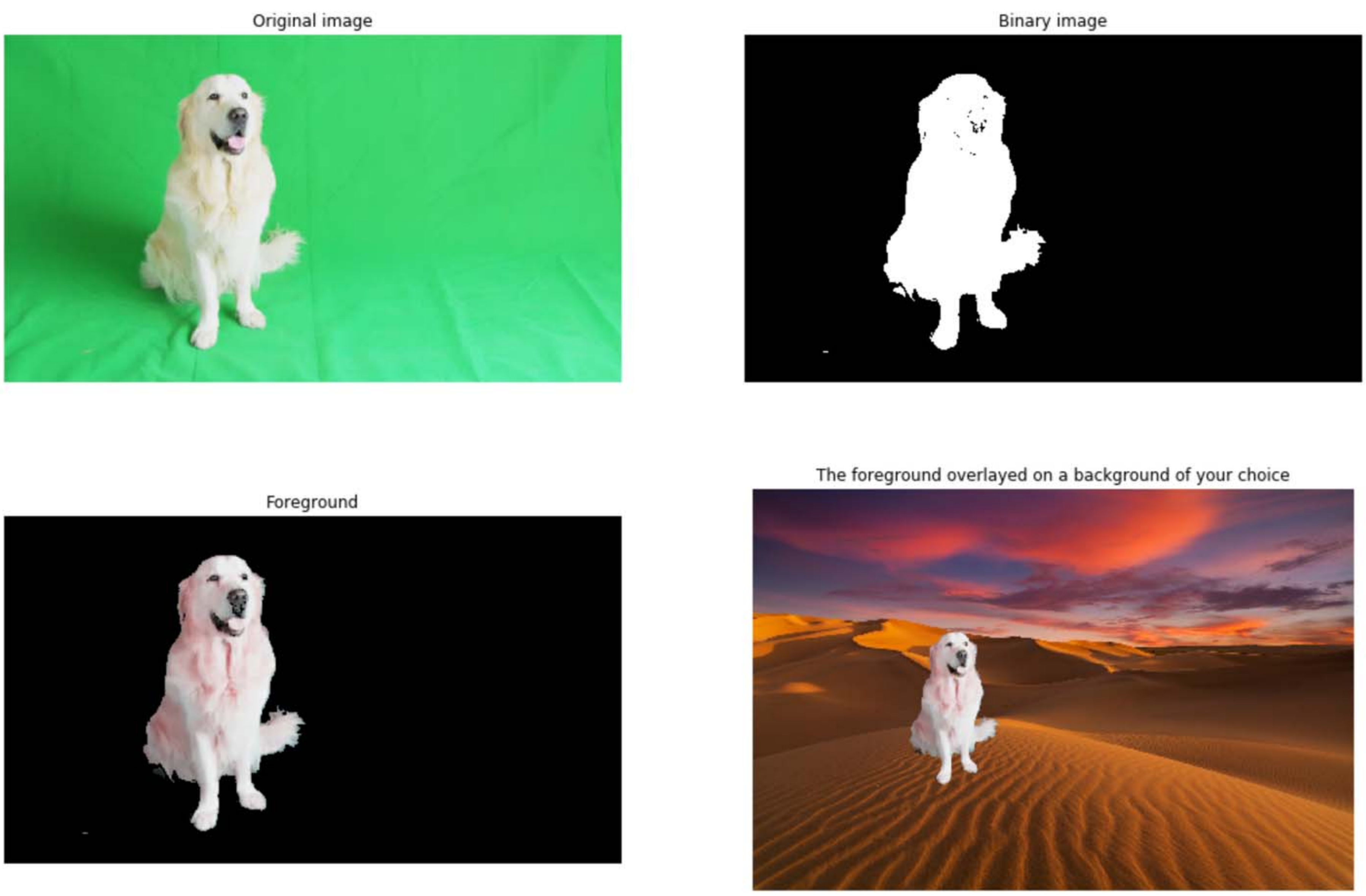
```
def foreground_dog(img, background):
    mask = np.zeros_like(img)
    R = img[:,:,0]
    G = img[:,:,1]
    B = img[:,:,2]
    mask = (G < 110) | (R > 120) | (B > 190)
    binary = np.where(mask, 1, 0)

    foreground = np.zeros_like(img)
    zero = np.zeros_like(img)
    foreground[:,:,0] = np.where(mask, img[:,:,0], zero[:,:,0])
    foreground[:,:,1] = np.where(mask, img[:,:,2], zero[:,:,1])
    foreground[:,:,2] = np.where(mask, img[:,:,2], zero[:,:,2])

    comb = copy.deepcopy(background)
    h, w = img.shape[0], img.shape[1]
    x, y = 200, 300
    comb[y:y+h,x:x+w,0] = np.where(mask, img[:,:,0], comb[y:y+h,x:x+w,0])
    comb[y:y+h,x:x+w,1] = np.where(mask, img[:,:,2], comb[y:y+h,x:x+w,1])
    comb[y:y+h,x:x+w,2] = np.where(mask, img[:,:,2], comb[y:y+h,x:x+w,2])

    return binary, foreground, comb
```

In [12]:

```
dog = plt.imread('dog.jpg')
desert = plt.imread('desert.jpg')
dog_binary, dog_fore, dog_comb = foreground_dog(dog, desert)

plt.figure(figsize=(18,12))

plt.subplot(2,2,1)
plt.title('Original image')
plt.axis('off')
plt.imshow(dog)

plt.subplot(2,2,2)
plt.title('Binary image')
plt.axis('off')
plt.imshow(dog_binary, cmap='gray')

plt.subplot(2,2,3)
plt.title('Foreground')
plt.axis('off')
plt.imshow(dog_fore)

plt.subplot(2,2,4)
plt.title('The foreground overlayed on a background of your choice')
plt.axis('off')
plt.imshow(dog_comb)
```

Out[12]:

```
<matplotlib.image.AxesImage at 0x24f0f6f5390>
```



Problem 5. Upsampling and downsampling

(i) List (and describe in a short paragraph) 3 interpolation methods.

(a) Nearest-neighbor interpolation
This is the simplest method. The nearest-neighbor interpolation method only considers the values of the nearest neighbor to get interpolation. Those empty pixels will be filled up with value of the nearest pixel. The values of the points are not considered. In general, the result of this method are not pretty good.

(b) Bilinear interpolation
Mathematically, this is a kind of extension of linear interpolation. Instead of using the only one neareast pixel, this method considers four values near the target, two in X-axis and two in Y-axis. The main idea is to implement linear interpolation on both the X-axis and Y-axis. Also, this the default method used by the "resize" function in Python OpenCV.

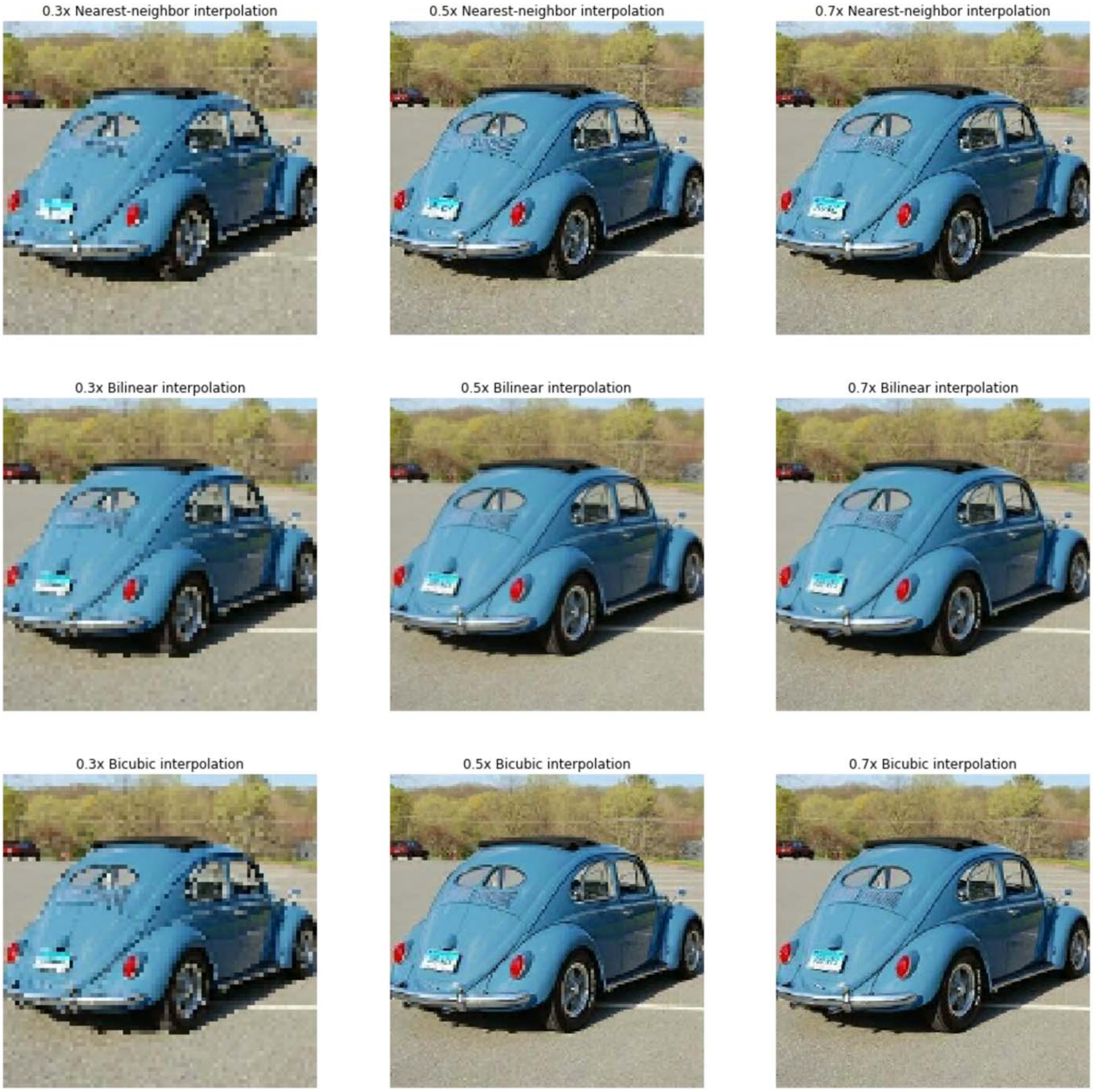
(c) Bicubic interpolation
Mathematically, this is a kind of extension of cubic interpolation. Instead of taking 4 neighbors' values, this method considers 16 values. The bicubic interpolation takes 4×4 square pixels and calculates their weighted arithmetic mean for resampling.

In [13]:
```
import cv2

beetle = cv2.imread('beetle.jpg')
lights = cv2.imread('lights.jpg')
rubiks = cv2.imread('rubiks.jpg')
```

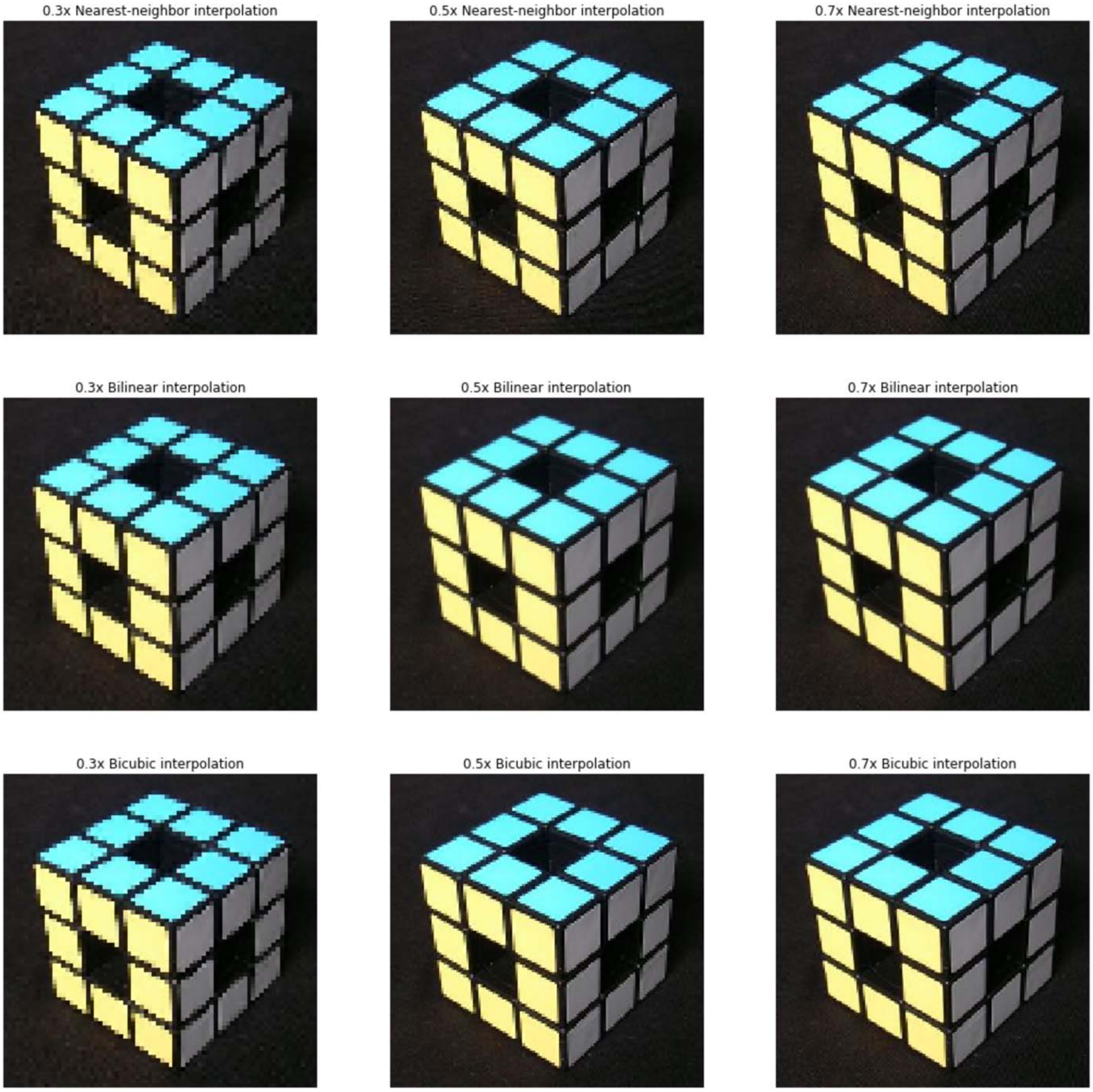
In [14]:

```
# downsampling

inter = [cv2.INTER_NEAREST, cv2.INTER_LINEAR, cv2.INTER_CUBIC]
ratio = [0.3, 0.5, 0.7]
title =  ['0.3x Nearest-neighbor interpolation',
          '0.5x Nearest-neighbor interpolation',
          '0.7x Nearest-neighbor interpolation',
          '0.3x Bilinear interpolation',
          '0.5x Bilinear interpolation',
          '0.7x Bilinear interpolation',
          '0.3x Bicubic interpolation',
          '0.5x Bicubic interpolation',
          '0.7x Bicubic interpolation']
beetle_ds = []
lights_ds = []
rubiks_ds = []

for i in range(len(inter)):
    for j in range(len(ratio)):
        # beetle
        beetle_size = (int(beetle.shape[1]*ratio[j]), int(beetle.shape[0]*ratio[j]))
        beetle_ds.append(cv2.resize(beetle, beetle_size, interpolation=inter[i]))
        # lights
        lights_size = (int(lights.shape[1]*ratio[j]), int(lights.shape[0]*ratio[j]))
        lights_ds.append(cv2.resize(lights, lights_size, interpolation=inter[i]))
        # rubiks
        rubiks_size = (int(rubiks.shape[1]*ratio[j]), int(rubiks.shape[0]*ratio[j]))
        rubiks_ds.append(cv2.resize(rubiks, rubiks_size, interpolation=inter[i]))

# transform image to rgb
for i in range(len(inter)*len(ratio)):
    beetle_ds[i] = beetle_ds[i][:,:,::-1]
    lights_ds[i] = lights_ds[i][:,:,::-1]
    rubiks_ds[i] = rubiks_ds[i][:,:,::-1]

print('(ii) Downsampling')

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(beetle_ds[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(lights_ds[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(rubiks_ds[i])
```

(ii) Downsampling




0.3x Nearest-neighbor interpolation
0.5x Nearest-neighbor interpolation
0.7x Nearest-neighbor interpolation
0.3x Bilinear interpolation
0.5x Bilinear interpolation
0.7x Bilinear interpolation
0.3x Bicubic interpolation
0.5x Bicubic interpolation
0.7x Bicubic interpolation



What differences do you observe? Which interpolation method do you think works best?

In 0.3x downsampling, those results are similar, looks like a lot of grids. I think the main reason is that the pixels are not enough to show a beautiful image of the original one. It doesn't matter which method we choose. In 0.5x downsampling, the results by Bilinear interpolation look blur, just like a painting. They are not as sharp as the results of Bicubic interpolation. In 0.7x downsampling, the edges in the results of Bicubic interpolation look even sharper. I think this image looks very similar to the original one. In general, I think Bicubic interpolation works best for downsampling.

In [15]:

```
# upsampling

inter = [cv2.INTER_NEAREST, cv2.INTER_LINEAR, cv2.INTER_CUBIC]
ratio = [1.5, 1.7, 2]
title =  ['1.5x Nearest-neighbor interpolation',
          '1.7x Nearest-neighbor interpolation',
          '2.0x Nearest-neighbor interpolation',
          '1.5x Bilinear interpolation',
          '1.7x Bilinear interpolation',
          '2.0x Bilinear interpolation',
          '1.5x Bicubic interpolation',
          '1.7x Bicubic interpolation',
          '2.0x Bicubic interpolation']
beetle_us = []
lights_us = []
rubiks_us = []

for i in range(len(inter)):
    for j in range(len(ratio)):
        # beetle
        beetle_size = (int(beetle.shape[1]*ratio[j]), int(beetle.shape[0]*ratio[j]))
        beetle_us.append(cv2.resize(beetle, beetle_size, interpolation=inter[i]))
        # lights
        lights_size = (int(lights.shape[1]*ratio[j]), int(lights.shape[0]*ratio[j]))
        lights_us.append(cv2.resize(lights, lights_size, interpolation=inter[i]))
        # rubiks
        rubiks_size = (int(rubiks.shape[1]*ratio[j]), int(rubiks.shape[0]*ratio[j]))
        rubiks_us.append(cv2.resize(rubiks, rubiks_size, interpolation=inter[i]))

# transform image to rgb
for i in range(len(inter)*len(ratio)):
    beetle_us[i] = beetle_us[i][:,:,::-1]
    lights_us[i] = lights_us[i][:,:,::-1]
    rubiks_us[i] = rubiks_us[i][:,:,::-1]

print('(iii) Upsampling')

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(beetle_us[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(lights_us[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)*len(ratio)):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(rubiks_us[i])
```

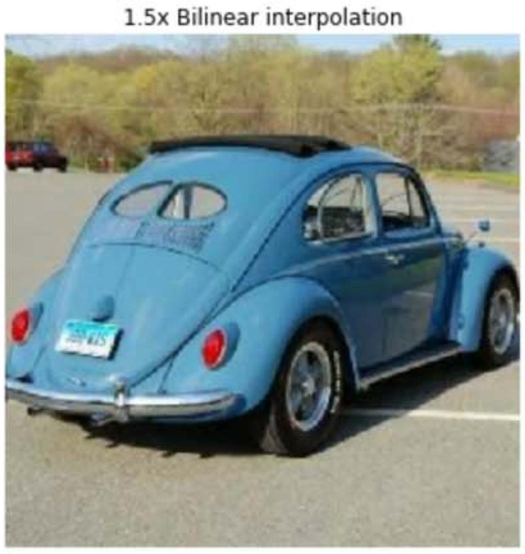
(iii) Upsampling

1.5x Nearest-neighbor interpolation

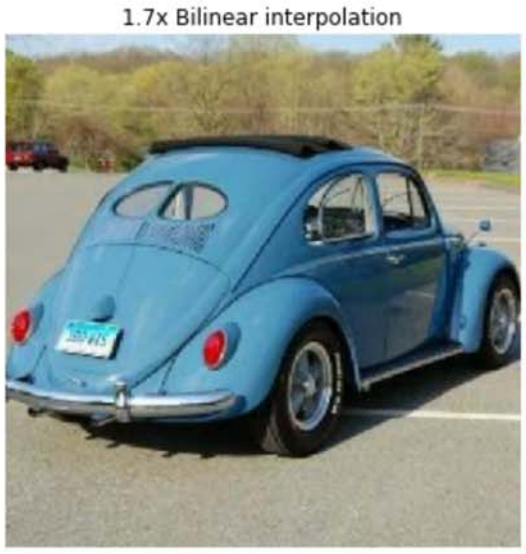
1.7x Nearest-neighbor interpolation

2.0x Nearest-neighbor interpolation

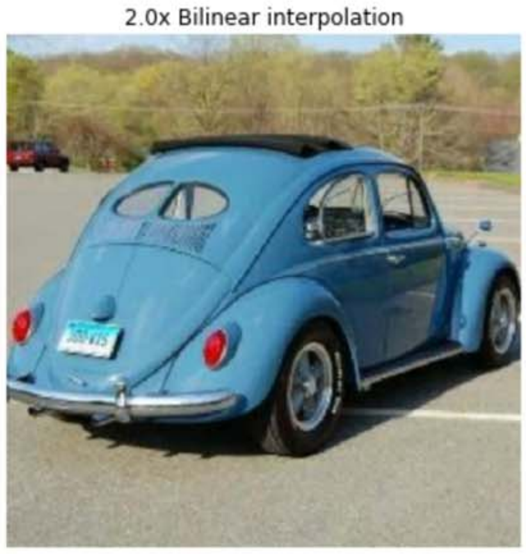
1.5x Bilinear interpolation



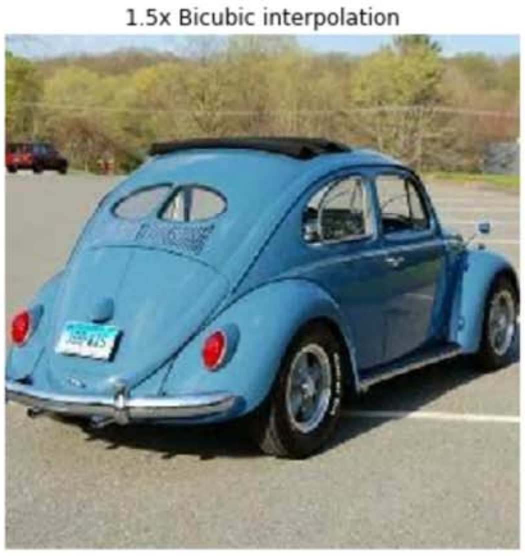
1.7x Bilinear interpolation



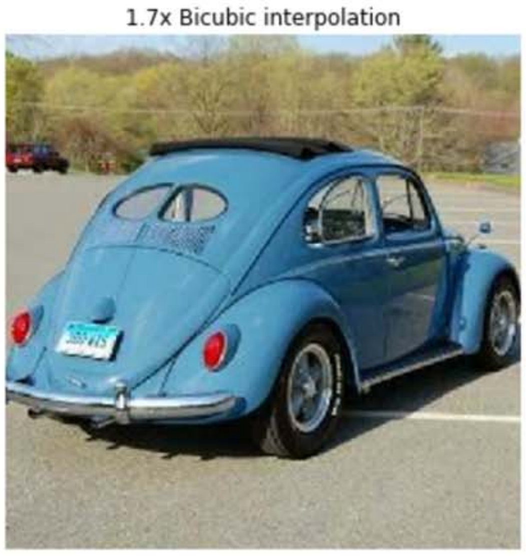
2.0x Bilinear interpolation



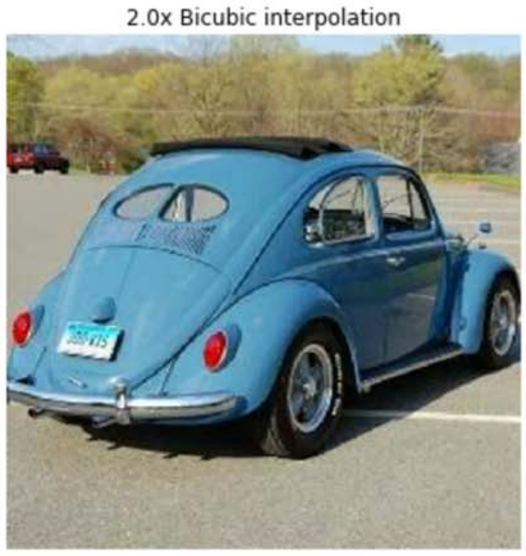
1.5x Bicubic interpolation



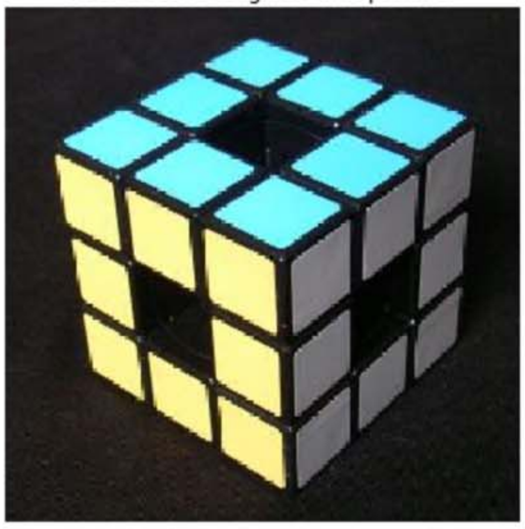
1.7x Bicubic interpolation

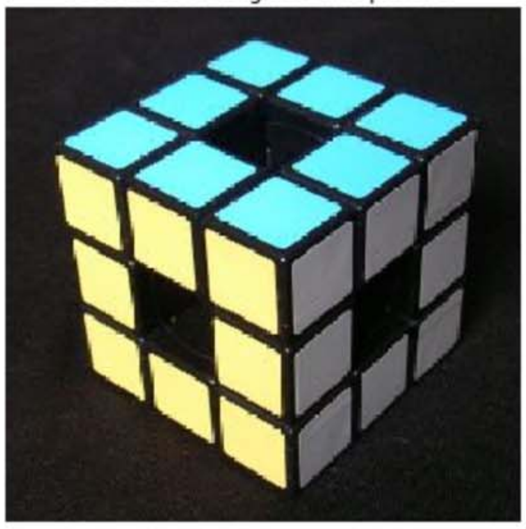


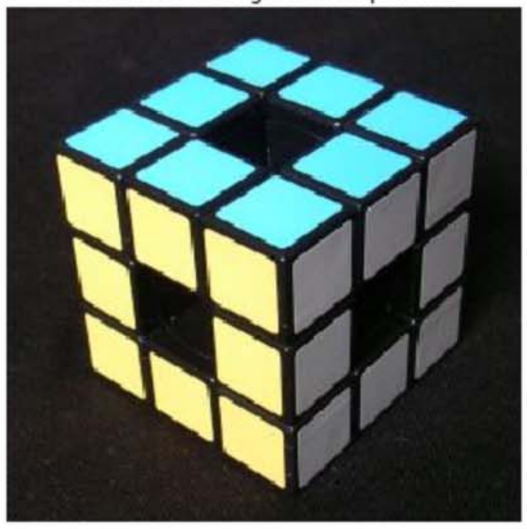
2.0x Bicubic interpolation

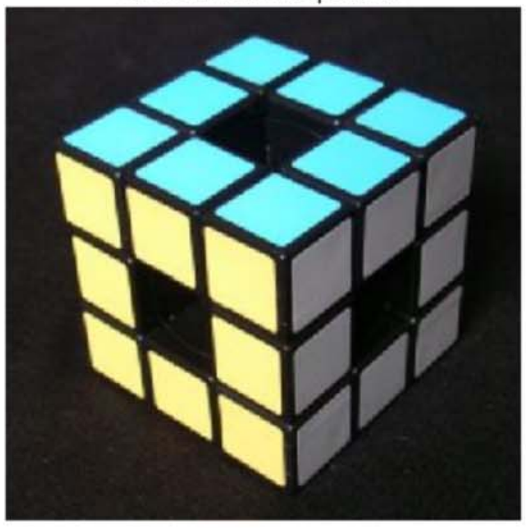


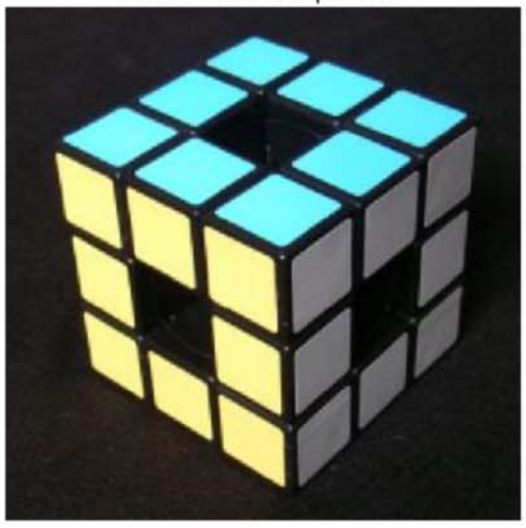

1.5x Nearest-neighbor interpolation
1.7x Nearest-neighbor interpolation
2.0x Nearest-neighbor interpolation
1.5x Bilinear interpolation
1.7x Bilinear interpolation
2.0x Bilinear interpolation
1.5x Bicubic interpolation
1.7x Bicubic interpolation
2.0x Bicubic interpolation

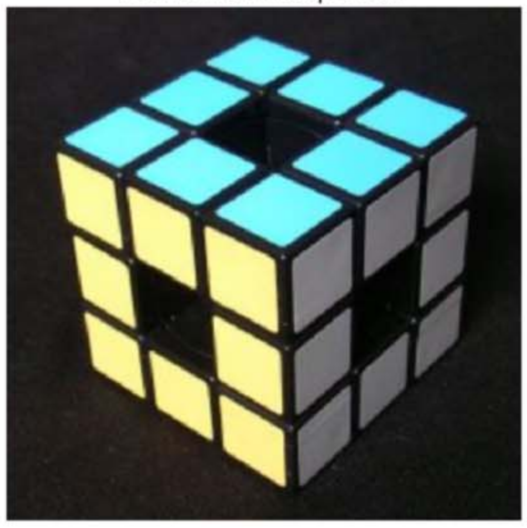

1.5x Nearest-neighbor interpolation

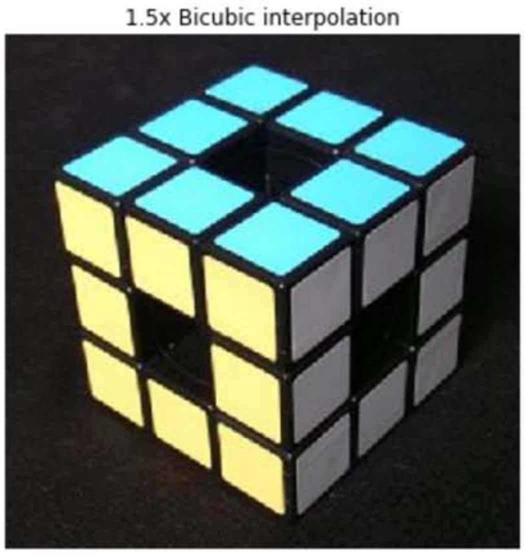

1.7x Nearest-neighbor interpolation

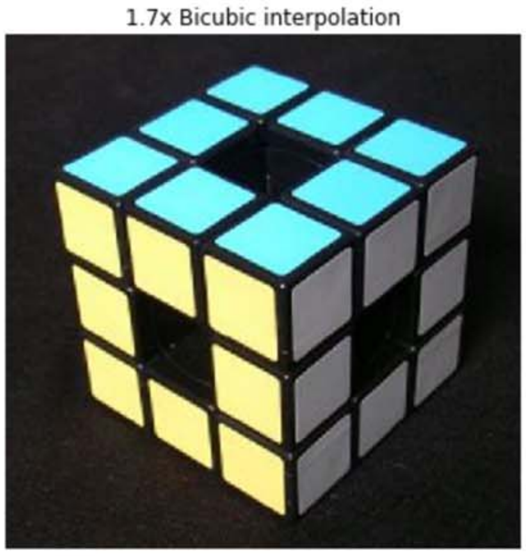

2.0x Nearest-neighbor interpolation

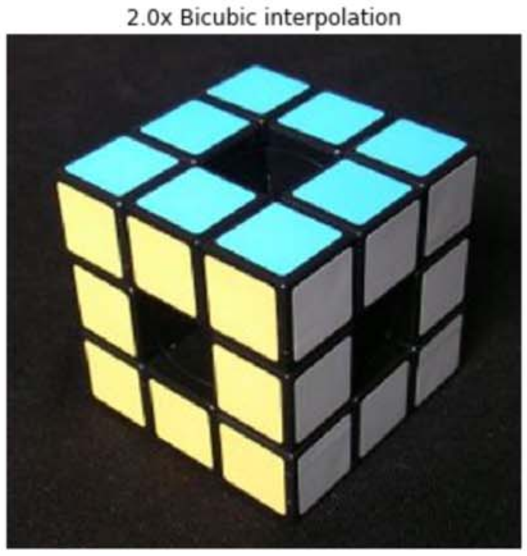

1.5x Bilinear interpolation


1.7x Bilinear interpolation


2.0x Bilinear interpolation


1.5x Bicubic interpolation

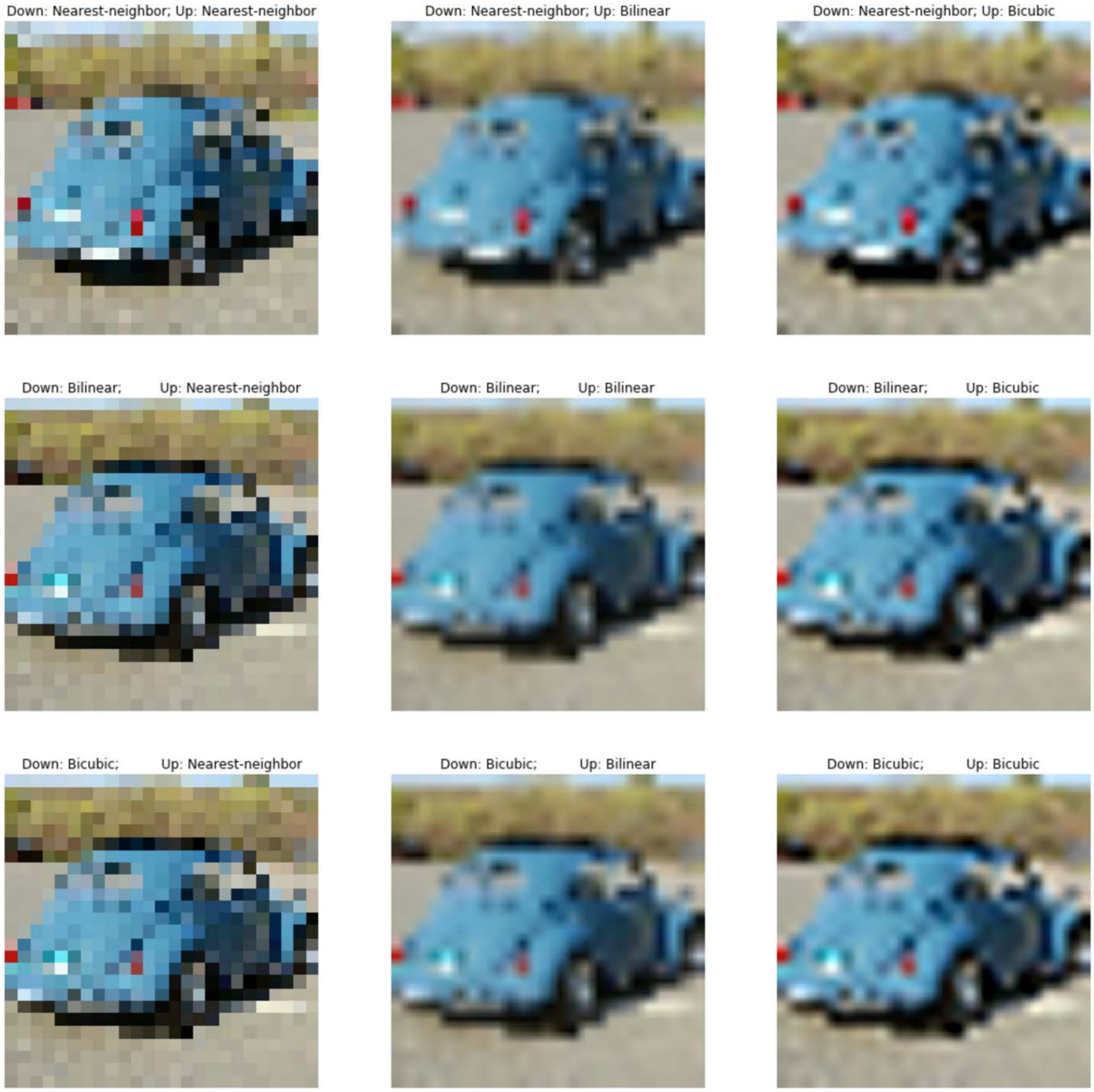

1.7x Bicubic interpolation


2.0x Bicubic interpolation

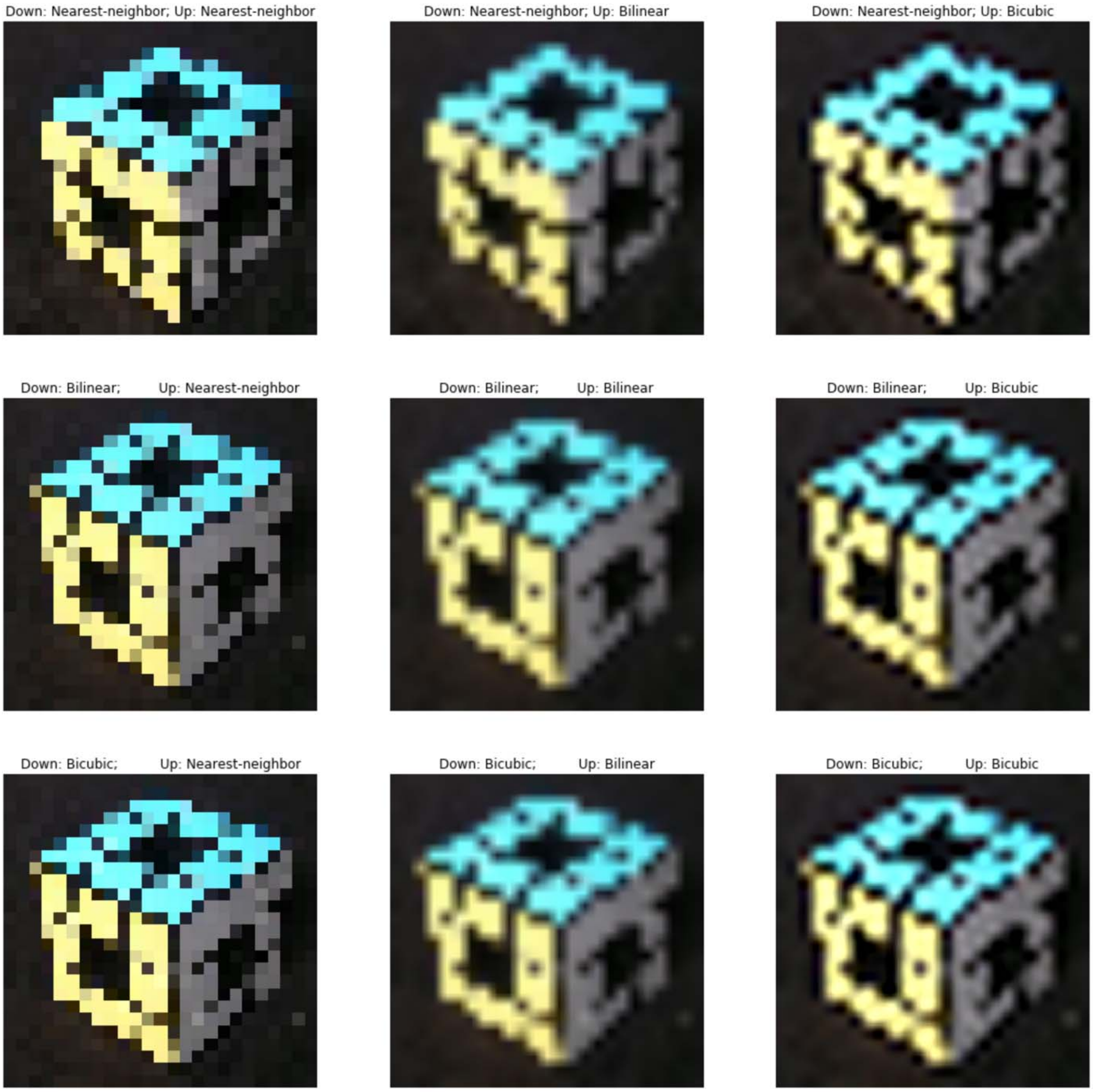
What differences do you observe? Which interpolation method do you think works best?
The results by Nearest-neighbor interpolation are worst. I can see some grids on the edge of objects. Also, the results of Bilinear interpolation look nice. However, compared to the results by Bicubic interpolation, they are a little bit blur. The edges of the object are not as sharp as the results of Bicubic interpolation. Thus, in general, I think Bicubic interpolation works best for upsampling.

In [16]:
```python
# reconstruction

inter = [cv2.INTER_NEAREST, cv2.INTER_LINEAR, cv2.INTER_CUBIC]
ratio = 0.1
title =  ['Down: Nearest-neighbor; Up: Nearest-neighbor',
          'Down: Nearest-neighbor; Up: Bilinear',
          'Down: Nearest-neighbor; Up: Bicubic',
          'Down: Bilinear;         Up: Nearest-neighbor',
          'Down: Bilinear;         Up: Bilinear',
          'Down: Bilinear;         Up: Bicubic',
          'Down: Bicubic;          Up: Nearest-neighbor',
          'Down: Bicubic;          Up: Bilinear',
          'Down: Bicubic;          Up: Bicubic']
beetle_r = []
lights_r = []
rubiks_r = []

for i in range(len(inter)):
    for j in range(len(inter)):
        # beetle
        beetle_size = (int(beetle.shape[1]*ratio), int(beetle.shape[0]*ratio))
        beetle_tmp = cv2.resize(beetle, beetle_size, interpolation=inter[i])
        beetle_size = (int(beetle.shape[1]), int(beetle.shape[0]))
        beetle_r.append(cv2.resize(beetle_tmp, beetle_size, interpolation=inter[j]))
        # lights
        lights_size = (int(lights.shape[1]*ratio), int(lights.shape[0]*ratio))
        lights_tmp = cv2.resize(lights, lights_size, interpolation=inter[i])
        lights_size = (int(lights.shape[1]), int(lights.shape[0]))
        lights_r.append(cv2.resize(lights_tmp, lights_size, interpolation=inter[j]))
        # rubiks
        rubiks_size = (int(rubiks.shape[1]*ratio), int(rubiks.shape[0]*ratio))
        rubiks_tmp = cv2.resize(rubiks, rubiks_size, interpolation=inter[i])
        rubiks_size = (int(rubiks.shape[1]), int(rubiks.shape[0]))
        rubiks_r.append(cv2.resize(rubiks_tmp, rubiks_size, interpolation=inter[j]))

# transform image to rgb
for i in range(len(inter)**2):
    beetle_r[i] = beetle_r[i][:,:,::-1]
    lights_r[i] = lights_r[i][:,:,::-1]
    rubiks_r[i] = rubiks_r[i][:,:,::-1]

print('(iv) Reconstruction')

plt.figure(figsize=(18,18))
for i in range(len(inter)**2):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(beetle_r[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)**2):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(lights_r[i])

plt.figure(figsize=(18,18))
for i in range(len(inter)**2):
    plt.subplot(3,3,i+1)
    plt.title(title[i])
    plt.axis('off')
    plt.imshow(rubiks_r[i])
```

(iv) Reconstruction




Down: Nearest-neighbor; Up: Nearest-neighbor
Down: Nearest-neighbor; Up: Bilinear
Down: Nearest-neighbor; Up: Bicubic
Down: Bilinear; Up: Nearest-neighbor
Down: Bilinear; Up: Bilinear
Down: Bilinear; Up: Bicubic
Down: Bicubic; Up: Nearest-neighbor
Down: Bicubic; Up: Bilinear
Down: Bicubic; Up: Bicubic



Which interpolation combination do you think works best to reconstruct the original image?
Among these 3 image reconstructions, I think downsampling by Bicubic interpolation and upsampling by Bilinear interpolation works best. The results of upsampling by nearest-neighbor interpolation are all terrible. I think that's because the nearest-neighbor interpolation for upsampling can only take the same value from its next pixel. That is the reason why the results contain a lot of blocks with the same color. The results of upsampling by Bicubic interpolation are not as smooth as using Bilinear interpolation. A lot of edges are sharper. However, I think many edges are not in the right place comparing to the original image.