ARI2129 Group Project - Task 4

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June 9, 2024

1 Importing necessary packages

[1]:
```
import git
import shutil
import os
import cv2
import numpy as np
import random
import matplotlib.pyplot as plt
%matplotlib inline
```

2 Setting directories for saving generated images

[2]:
```
saved_imgs_dir = 'augmented_imgs'
```

[3]:
```
photo_dist_dir = 'photometric'
```

[4]:
```
geo_dist_dir = 'geometric'
```

3 Removing any images present in the sub-directories

[5]:
```
for img in os.listdir(saved_imgs_dir+'/'+photo_dist_dir):
    os.remove(saved_imgs_dir+'/'+photo_dist_dir+'/'+img)
```

[6]:
```
for img in os.listdir(saved_imgs_dir+'/'+geo_dist_dir):
    os.remove(saved_imgs_dir+'/'+geo_dist_dir+'/'+img)
```

4 Accessing COTS Dataset

4.1 Cloning the dataset from GitHub to local storage

[7]:
```
# Packages Install
!pip install gitpython

# Cloning repository
repo_url = 'https://github.com/dylanseychell/COTSDataset.git'
```

```
repo_dir = 'COTSDataset'  # Directory to clone the repository into

# Checking if the repository directory already exists
if not os.path.exists(repo_dir):
    # Cloning repository
    git.Repo.clone_from(repo_url, repo_dir)
    print("Repository cloned successfully.")
else:
    print("Repository already cloned.")

# Defining paths
part1_single_objects = os.path.join(repo_dir, "Part 1 - Single Objects")
part2_multiple_objects = os.path.join(repo_dir, "Part 2 - Multiple Objects")
part3_complex_background = os.path.join(repo_dir, "Part 3 - Complex Background")

print("Repository cloned successfully.")
```

```
Requirement already satisfied: gitpython in c:\users\mvass\anaconda3\lib\site-
packages (3.1.37)
Requirement already satisfied: gitdb<5,>=4.0.1 in
c:\users\mvass\anaconda3\lib\site-packages (from gitpython) (4.0.7)
Requirement already satisfied: smmap<5,>=3.0.1 in
c:\users\mvass\anaconda3\lib\site-packages (from gitdb<5,>=4.0.1->gitpython)
(4.0.0)
Repository already cloned.
Repository cloned successfully.
```

[8]:
```
os.listdir('COTSDataset')
```

[8]:
```
['.DS_Store',
 '.git',
 'LICENSE',
 'Part 1 - Single Objects',
 'Part 2 - Multiple Objects',
 'Part 3 - Complex Background',
 'Pointer Data',
 'README.md',
 'Videos']
```

4.2 Getting a random 5 images from the dataset

4.2.1 Setting paths to images in the dataset

[9]:
```
single_obj_path = repo_dir+'/Part 1 - Single Objects'
mult_obj_path = repo_dir+'/Part 2 - Multiple Objects'
complex_bg_path = repo_dir+'/Part 3 - Complex Background'
```

4.2.2 Getting all images from each path and placing them in their own list

[10]:
```
def get_images_from_folder(main_path):
    imgs_list = []
    for sub_path in os.listdir(main_path):
        sub_list = []
        for file in os.listdir(main_path+"/"+sub_path):
            if file.endswith(".jpeg") or file.endswith(".png"):
                sub_list.append(main_path+"/"+sub_path+"/"+file)
        imgs_list.append(sub_list)

    return imgs_list
```

[11]:
```
single_obj_imgs = get_images_from_folder(single_obj_path)

# Removing any empty sublists contained in the main list
single_obj_imgs = [img_list for img_list in single_obj_imgs if img_list != []]

single_obj_imgs
```

[11]:
```
[['COTSDataset/Part 1 - Single Objects/objects/beer_mug_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/beer_mug_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/beer_mug_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/beer_mug_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/boots_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/boots_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/boots_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/boots_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/bosnia_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/bosnia_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/bosnia_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/bosnia_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/bowl_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/bowl_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/bowl_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/bowl_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/buddha_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/buddha_depth16.png',
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  'COTSDataset/Part 1 - Single Objects/objects/buddha_depth8_nofill.png',
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  'COTSDataset/Part 1 - Single Objects/objects/cap_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/cap_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/cap_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v1_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v1_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v1_depth8.png',
```

```
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v1_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v2_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v2_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v2_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/cardboard_v2_depth8_nofill.png',
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  'COTSDataset/Part 1 - Single Objects/objects/cmt_mug_depth16.png',
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  'COTSDataset/Part 1 - Single Objects/objects/elephant_depth8.png',
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```

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'COTSDataset/Part 1 - Single Objects/objects/shaving_foam_depth8.png',
'COTSDataset/Part 1 - Single Objects/objects/shaving_foam_depth8_nofill.png',
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'COTSDataset/Part 1 - Single Objects/objects/shooter_glass1_depth16.png',

```
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  'COTSDataset/Part 1 - Single
Objects/objects/shooter_glass1_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass2_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass2_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass2_depth8.png',
  'COTSDataset/Part 1 - Single
Objects/objects/shooter_glass2_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass3_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass3_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/shooter_glass3_depth8.png',
  'COTSDataset/Part 1 - Single
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  'COTSDataset/Part 1 - Single Objects/objects/sneakers_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/sneakers_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/sneakers_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/tajin_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/tajin_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/tajin_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/tajin_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/travel_mug_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/travel_mug_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/travel_mug_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/travel_mug_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/objects/volcano_colour.jpeg',
  'COTSDataset/Part 1 - Single Objects/objects/volcano_depth16.png',
  'COTSDataset/Part 1 - Single Objects/objects/volcano_depth8.png',
  'COTSDataset/Part 1 - Single Objects/objects/volcano_depth8_nofill.png'],
 ['COTSDataset/Part 1 - Single Objects/scene_green/empty_colour.jpeg',
  'COTSDataset/Part 1 - Single
Objects/scene_green/empty_controlled_colour.jpeg',
  'COTSDataset/Part 1 - Single
Objects/scene_green/empty_controlled_depth16.png',
  'COTSDataset/Part 1 - Single Objects/scene_green/empty_controlled_depth8.png',
  'COTSDataset/Part 1 - Single
Objects/scene_green/empty_controlled_depth8_nofill.png',
  'COTSDataset/Part 1 - Single Objects/scene_green/empty_depth16.png',
  'COTSDataset/Part 1 - Single Objects/scene_green/empty_depth8.png',
  'COTSDataset/Part 1 - Single Objects/scene_green/empty_depth8_nofill.png']]
```

[12]:
```
mult_obj_imgs = get_images_from_folder(mult_obj_path)

# Removing any empty sublists contained in the main list
mult_obj_imgs = [img_list for img_list in mult_obj_imgs if img_list != []]

mult_obj_imgs
```

```
[12]: [['COTSDataset/Part 2 - Multiple Objects/academic_book_no/1_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/1_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/1_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/1_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/2_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/2_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/2_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/2_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/3_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/3_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/3_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_no/3_depth8_nofill.png'],
       ['COTSDataset/Part 2 - Multiple Objects/academic_book_oc/1_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/1_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/1_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/1_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/2_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/2_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/2_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/2_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/3_colour.jpeg',
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        'COTSDataset/Part 2 - Multiple Objects/academic_book_oc/3_depth8.png',
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       ['COTSDataset/Part 2 - Multiple Objects/food_no/1_colour.jpeg',
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        'COTSDataset/Part 2 - Multiple Objects/food_no/1_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/1_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/2_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/food_no/2_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/2_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/2_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/3_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/food_no/3_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/3_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/3_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/4_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/food_no/4_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/4_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/food_no/4_depth8_nofill.png'],
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        'COTSDataset/Part 2 - Multiple Objects/food_oc/1_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/food_oc/1_depth8.png',
        'COTSDataset/Part 2 - Multiple Objects/food_oc/1_depth8_nofill.png',
        'COTSDataset/Part 2 - Multiple Objects/food_oc/2_colour.jpeg',
        'COTSDataset/Part 2 - Multiple Objects/food_oc/2_depth16.png',
        'COTSDataset/Part 2 - Multiple Objects/food_oc/2_depth8.png',
```

```
 'COTSDataset/Part 2 - Multiple Objects/food_oc/2_depth8_nofill.png',
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 'COTSDataset/Part 2 - Multiple Objects/mugs_no/4_colour.jpeg',
```

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 'COTSDataset/Part 2 - Multiple Objects/souvenirs_no/3_depth8.png',
 'COTSDataset/Part 2 - Multiple Objects/souvenirs_no/3_depth8_nofill.png',
 'COTSDataset/Part 2 - Multiple Objects/souvenirs_no/4_colour.jpeg',
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 'COTSDataset/Part 2 - Multiple Objects/tech_oc/3_depth16.png',
 'COTSDataset/Part 2 - Multiple Objects/tech_oc/3_depth8.png',
 'COTSDataset/Part 2 - Multiple Objects/tech_oc/3_depth8_nofill.png'],
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 'COTSDataset/Part 2 - Multiple Objects/vr_no/2_depth8.png',
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 'COTSDataset/Part 2 - Multiple Objects/vr_oc/1_depth8_nofill.png',
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 'COTSDataset/Part 2 - Multiple Objects/vr_oc/2_depth8.png',
 'COTSDataset/Part 2 - Multiple Objects/vr_oc/2_depth8_nofill.png',
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```
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 'COTSDataset/Part 2 - Multiple Objects/wash_oc/3_depth8.png',
 'COTSDataset/Part 2 - Multiple Objects/wash_oc/3_depth8_nofill.png']]
```

[13]:
```
complex_bg_imgs = get_images_from_folder(complex_bg_path)

# Removing any empty sublists contained in the main list
complex_bg_imgs = [img_list for img_list in complex_bg_imgs if img_list != []]

complex_bg_imgs
```

[13]:
```
[['COTSDataset/Part 3 - Complex Background/booksA_nw_no/1_colour.jpeg',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/1_depth16.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/1_depth8.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/1_depth8_nofill.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/2_colour.jpeg',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/2_depth16.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/2_depth8.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/2_depth8_nofill.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/3_colour.jpeg',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/3_depth16.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/3_depth8.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_no/3_depth8_nofill.png'],
 ['COTSDataset/Part 3 - Complex Background/booksA_nw_oc/1_colour.jpeg',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/1_depth16.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/1_depth8.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/1_depth8_nofill.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/2_colour.jpeg',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/2_depth16.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/2_depth8.png',
  'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/2_depth8_nofill.png',
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 'COTSDataset/Part 3 - Complex Background/booksA_nw_oc/3_depth8_nofill.png'],
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```

4.2.3 Putting each list in one whole list for easier access

[14]:
```
img_main_list = [single_obj_imgs, mult_obj_imgs, complex_bg_imgs]
```

4.2.4 Picking 5 random images from img_main_list

[15]:
```
# List to store selected images
imgs_selected_list = []

# Variable to store length of list
list_len = 0
```

```
# Repeat this loop until 5 images are selected
while list_len < 5:
    # Choose a sublist at random
    index = random.randrange(len(img_main_list))
    img_list_selected = random.choice(img_main_list[index])

    # Choose an image from the selected sublist
    img_selected = random.choice(img_list_selected)

    # Including only images with colour
    if "empty" not in img_selected and "nofill" not in img_selected and "depth"␣
 ↪not in img_selected:
        imgs_selected_list.append(img_selected)
        list_len += 1

imgs_selected_list
```

[15]:
```
['COTSDataset/Part 3 - Complex Background/statuesA_nw_no/3_colour.jpeg',
 'COTSDataset/Part 2 - Multiple Objects/wash_oc/1_colour.jpeg',
 'COTSDataset/Part 1 - Single Objects/objects/flipflop_colour.jpeg',
 'COTSDataset/Part 3 - Complex Background/statuesB_w_no/1_colour.jpeg',
 'COTSDataset/Part 3 - Complex Background/bottlesB_nw_no/3_colour.jpeg']
```

[16]:
```
img_selected = cv2.imread(random.choice(imgs_selected_list))   # for testing␣
 ↪purposes
```

[17]:
```
# for testing purposes
height, width = img_selected.shape[:2]
center = (width / 2, height / 2)
center
```

[17]:
```
(640.0, 360.0)
```

5 1. Photometric Distortions

5.1 Functions to do the three distortions below (contrast, brightness and saturation adjustment) using first principles

[18]:
```
def adjust_image_contrast(img, contrast_val):
    new_img = cv2.convertScaleAbs(img, alpha=contrast_val, beta=0)
    return new_img
```

[19]:
```
def adjust_image_brightness(img, bright_val):
    new_img = cv2.convertScaleAbs(img, alpha=1.0, beta=bright_val)
    return new_img
```

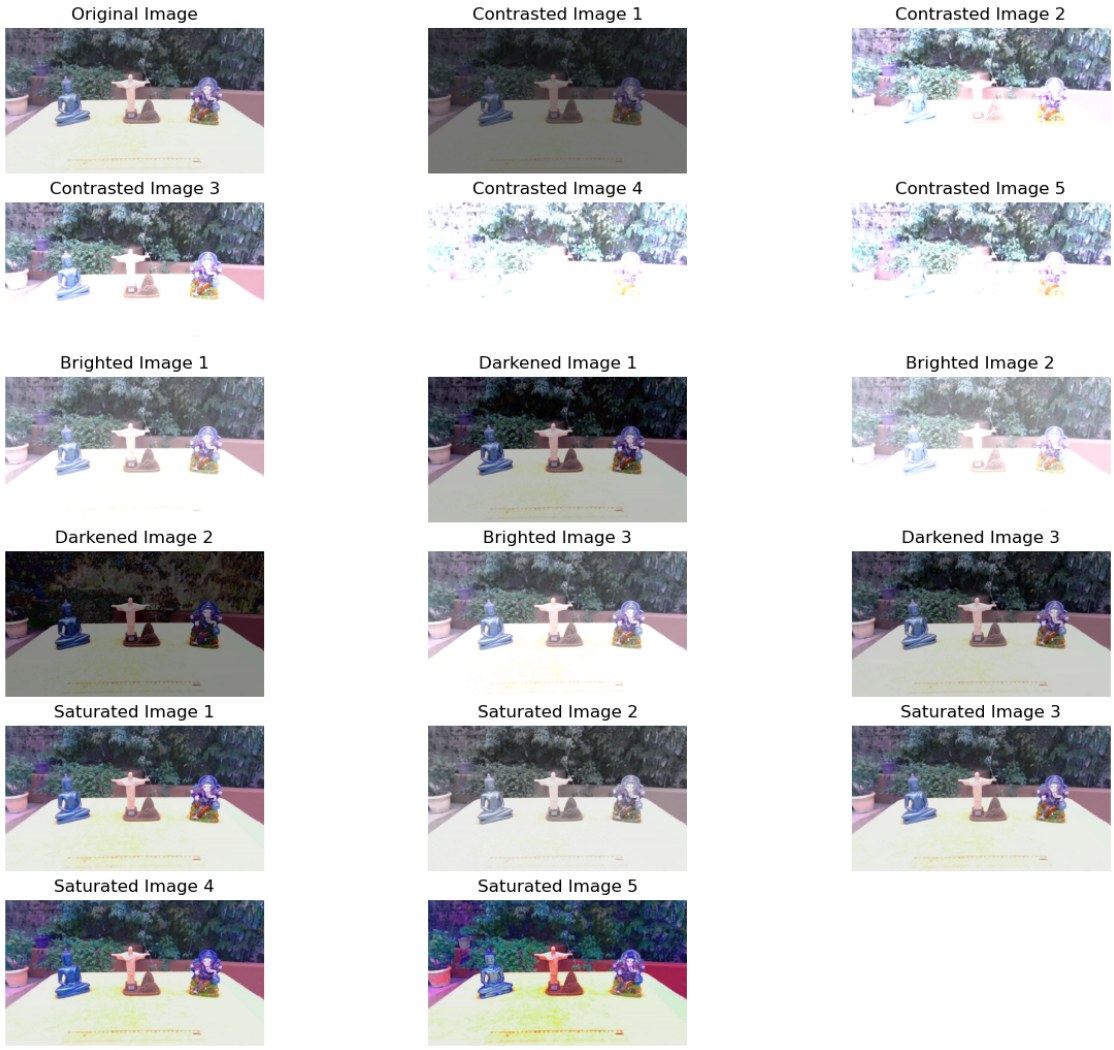
[20]:
```
def adjust_image_saturation(img, sat_factor):
    hsv_img = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)
    hsv_img[:, :, 1] = hsv_img[:, :, 1] * sat_factor
    saturated_img = cv2.cvtColor(hsv_img, cv2.COLOR_HSV2BGR)
    return saturated_img
```

5.2 Applying each distortion to the selected images and displaying them in order

There are 6 generated images by adjusting the brightness (3 brightened images + 3 darkened images)

[21]:
```
fig, axes = plt.subplots(nrows=7, ncols=3, figsize=(15, 15), squeeze=False)
gs = axes[0,0].get_gridspec()

current_image = cv2.imread(imgs_selected_list[0])
plt_size = gs.ncols * gs.nrows

cont_selected_1 = adjust_image_contrast(current_image, 0.5)
cont_selected_2 = adjust_image_contrast(current_image, 2.0)
cont_selected_3 = adjust_image_contrast(current_image, 1.5)
cont_selected_4 = adjust_image_contrast(current_image, 3.0)
cont_selected_5 = adjust_image_contrast(current_image, 2.5)
bright_selected_1 = adjust_image_brightness(current_image, 50)
dark_selected_1 = adjust_image_brightness(current_image, -50)
bright_selected_2 = adjust_image_brightness(current_image, 100)
dark_selected_2 = adjust_image_brightness(current_image, -100)
bright_selected_3 = adjust_image_brightness(current_image, 30)
dark_selected_3 = adjust_image_brightness(current_image, -30)
sat_selected_1 = adjust_image_saturation(current_image, 1.5)
sat_selected_2 = adjust_image_saturation(current_image, 0.5)
sat_selected_3 = adjust_image_saturation(current_image, 1.2)
sat_selected_4 = adjust_image_saturation(current_image, 2.1)
sat_selected_5 = adjust_image_saturation(current_image, 3.5)

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': cont_selected_1,  'title': 'Contrasted Image␣
 ↪1'},
              {'generated_image': cont_selected_2,  'title': 'Contrasted Image␣
 ↪2'},
              {'generated_image': cont_selected_3,  'title': 'Contrasted Image␣
 ↪3'},
              {'generated_image': cont_selected_4,  'title': 'Contrasted Image␣
 ↪4'},
              {'generated_image': cont_selected_5,  'title': 'Contrasted Image␣
 ↪5'},
```

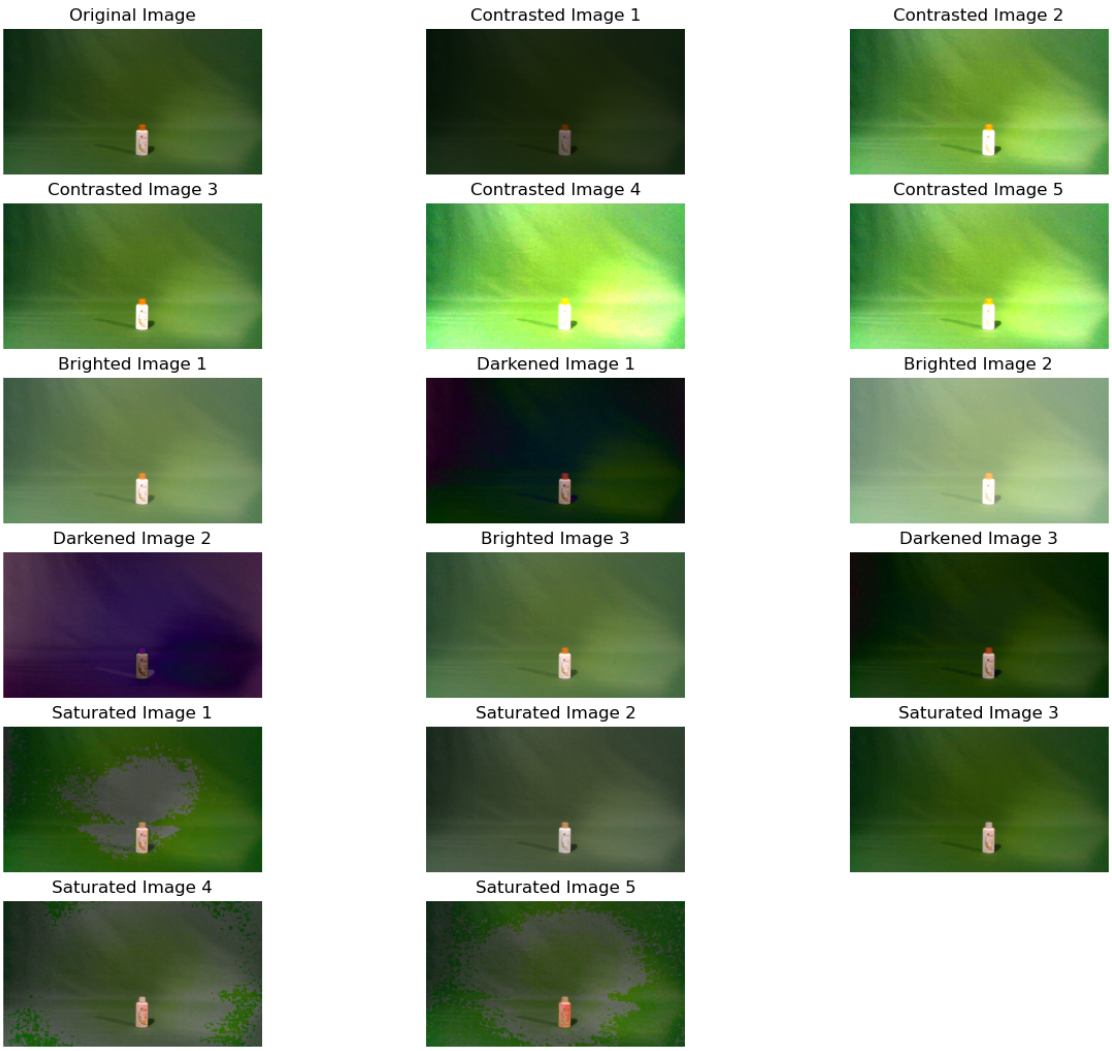
```
            {'generated_image': bright_selected_1, 'title': 'Brighted Image␣
 ↪1'},
            {'generated_image': dark_selected_1, 'title': 'Darkened Image 1'},
            {'generated_image': bright_selected_2, 'title': 'Brighted Image␣
 ↪2'},
            {'generated_image': dark_selected_2, 'title': 'Darkened Image 2'},
            {'generated_image': bright_selected_3, 'title': 'Brighted Image␣
 ↪3'},
            {'generated_image': dark_selected_3, 'title': 'Darkened Image 3'},
            {'generated_image': sat_selected_1, 'title': 'Saturated Image 1'},
            {'generated_image': sat_selected_2, 'title': 'Saturated Image 2'},
            {'generated_image': sat_selected_3, 'title': 'Saturated Image 3'},
            {'generated_image': sat_selected_4, 'title': 'Saturated Image 4'},
            {'generated_image': sat_selected_5, 'title': 'Saturated Image 5'}
           ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[0][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_1_'+str(row)+str(col)+imgs_selected_list[0][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_1_'+str(row)+str(col)+imgs_selected_list[0][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(1%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[22]:
```
fig, axes = plt.subplots(nrows=7, ncols=3, figsize=(15, 15), squeeze=False)
gs = axes[0,0].get_gridspec()

current_image = cv2.imread(imgs_selected_list[1])
plt_size = gs.ncols * gs.nrows

cont_selected_1 = adjust_image_contrast(current_image, 0.5)
cont_selected_2 = adjust_image_contrast(current_image, 2.0)
cont_selected_3 = adjust_image_contrast(current_image, 1.5)
cont_selected_4 = adjust_image_contrast(current_image, 3.0)
cont_selected_5 = adjust_image_contrast(current_image, 2.5)
bright_selected_1 = adjust_image_brightness(current_image, 50)
dark_selected_1 = adjust_image_brightness(current_image, -50)
bright_selected_2 = adjust_image_brightness(current_image, 100)
```

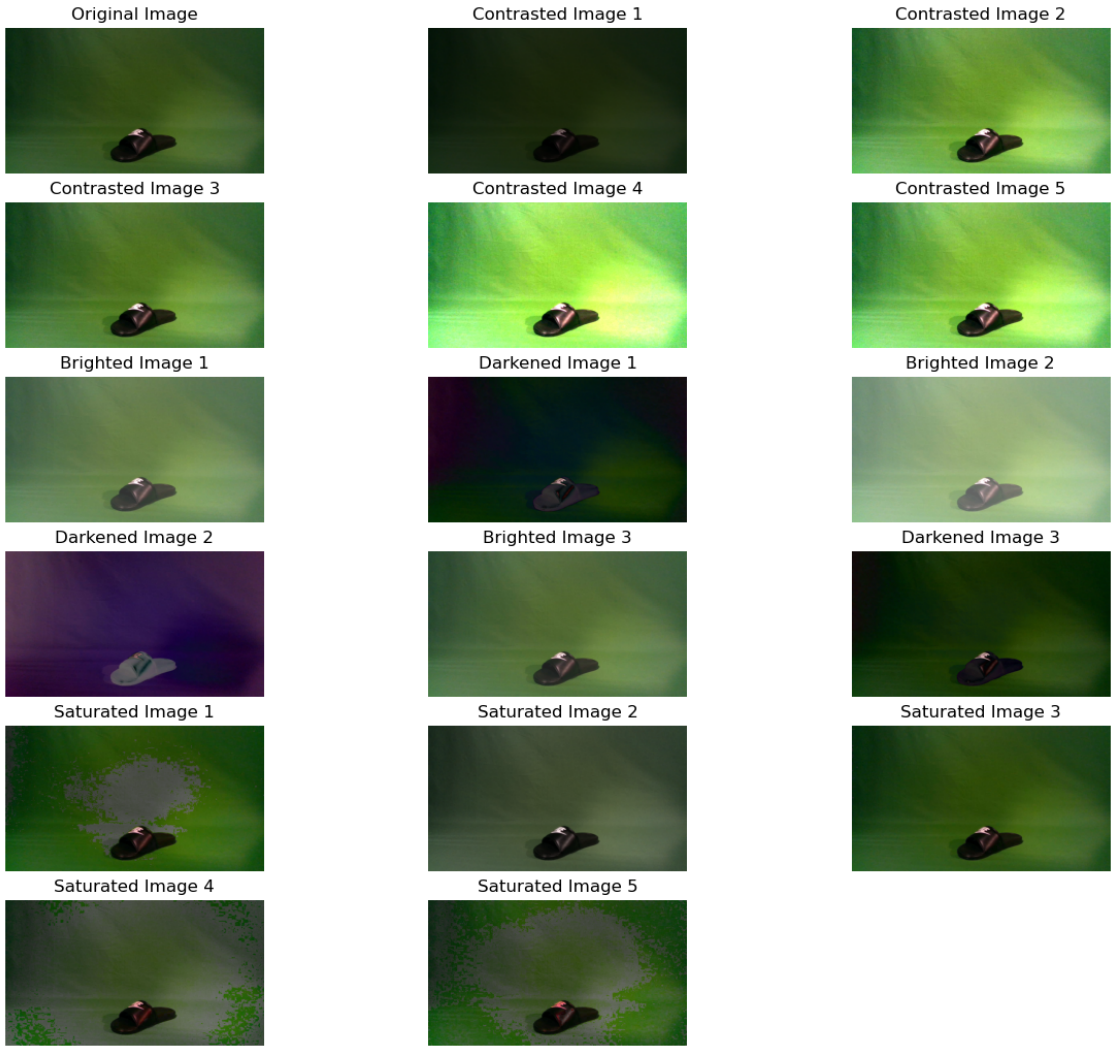
```
dark_selected_2 = adjust_image_brightness(current_image, -100)
bright_selected_3 = adjust_image_brightness(current_image, 30)
dark_selected_3 = adjust_image_brightness(current_image, -30)
sat_selected_1 = adjust_image_saturation(current_image, 1.5)
sat_selected_2 = adjust_image_saturation(current_image, 0.5)
sat_selected_3 = adjust_image_saturation(current_image, 1.2)
sat_selected_4 = adjust_image_saturation(current_image, 2.1)
sat_selected_5 = adjust_image_saturation(current_image, 3.5)

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': cont_selected_1,  'title': 'Contrasted Image␣
 ↪1'},
              {'generated_image': cont_selected_2,  'title': 'Contrasted Image␣
 ↪2'},
              {'generated_image': cont_selected_3,  'title': 'Contrasted Image␣
 ↪3'},
              {'generated_image': cont_selected_4,  'title': 'Contrasted Image␣
 ↪4'},
              {'generated_image': cont_selected_5,  'title': 'Contrasted Image␣
 ↪5'},
              {'generated_image': bright_selected_1, 'title': 'Brighted Image␣
 ↪1'},
              {'generated_image': dark_selected_1, 'title': 'Darkened Image 1'},
              {'generated_image': bright_selected_2, 'title': 'Brighted Image␣
 ↪2'},
              {'generated_image': dark_selected_2, 'title': 'Darkened Image 2'},
              {'generated_image': bright_selected_3, 'title': 'Brighted Image␣
 ↪3'},
              {'generated_image': dark_selected_3, 'title': 'Darkened Image 3'},
              {'generated_image': sat_selected_1, 'title': 'Saturated Image 1'},
              {'generated_image': sat_selected_2, 'title': 'Saturated Image 2'},
              {'generated_image': sat_selected_3, 'title': 'Saturated Image 3'},
              {'generated_image': sat_selected_4, 'title': 'Saturated Image 4'},
              {'generated_image': sat_selected_5, 'title': 'Saturated Image 5'}
             ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[1][-5:] == ".jpeg":
```

```
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_2_'+str(row)+str(col)+imgs_selected_list[1][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_2_'+str(row)+str(col)+imgs_selected_list[1][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(1%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[23]:
```
fig, axes = plt.subplots(nrows=7, ncols=3, figsize=(15, 15), squeeze=False)
gs = axes[0,0].get_gridspec()

current_image = cv2.imread(imgs_selected_list[2])
plt_size = gs.ncols * gs.nrows

cont_selected_1 = adjust_image_contrast(current_image, 0.5)
cont_selected_2 = adjust_image_contrast(current_image, 2.0)
cont_selected_3 = adjust_image_contrast(current_image, 1.5)
cont_selected_4 = adjust_image_contrast(current_image, 3.0)
cont_selected_5 = adjust_image_contrast(current_image, 2.5)
bright_selected_1 = adjust_image_brightness(current_image, 50)
dark_selected_1 = adjust_image_brightness(current_image, -50)
bright_selected_2 = adjust_image_brightness(current_image, 100)
dark_selected_2 = adjust_image_brightness(current_image, -100)
bright_selected_3 = adjust_image_brightness(current_image, 30)
dark_selected_3 = adjust_image_brightness(current_image, -30)
sat_selected_1 = adjust_image_saturation(current_image, 1.5)
sat_selected_2 = adjust_image_saturation(current_image, 0.5)
sat_selected_3 = adjust_image_saturation(current_image, 1.2)
sat_selected_4 = adjust_image_saturation(current_image, 2.1)
sat_selected_5 = adjust_image_saturation(current_image, 3.5)

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': cont_selected_1,  'title': 'Contrasted Image␣
 ↪1'},
              {'generated_image': cont_selected_2,  'title': 'Contrasted Image␣
 ↪2'},
              {'generated_image': cont_selected_3,  'title': 'Contrasted Image␣
 ↪3'},
              {'generated_image': cont_selected_4,  'title': 'Contrasted Image␣
 ↪4'},
              {'generated_image': cont_selected_5,  'title': 'Contrasted Image␣
 ↪5'},
              {'generated_image': bright_selected_1, 'title': 'Brighted Image␣
 ↪1'},
              {'generated_image': dark_selected_1, 'title': 'Darkened Image 1'},
              {'generated_image': bright_selected_2, 'title': 'Brighted Image␣
 ↪2'},
              {'generated_image': dark_selected_2, 'title': 'Darkened Image 2'},
              {'generated_image': bright_selected_3, 'title': 'Brighted Image␣
 ↪3'},
              {'generated_image': dark_selected_3, 'title': 'Darkened Image 3'},
              {'generated_image': sat_selected_1, 'title': 'Saturated Image 1'},
              {'generated_image': sat_selected_2, 'title': 'Saturated Image 2'},
              {'generated_image': sat_selected_3, 'title': 'Saturated Image 3'},
```

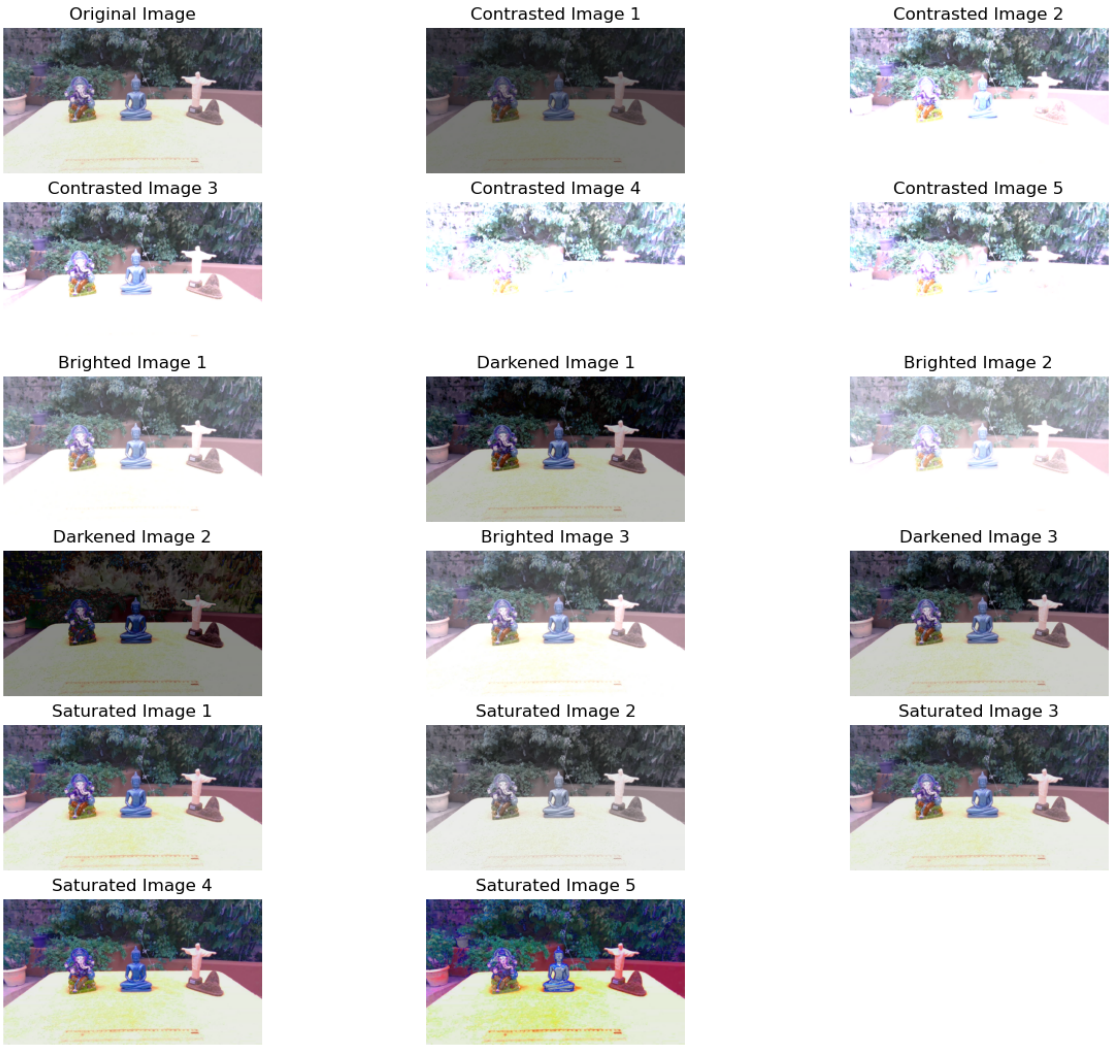
```
            {'generated_image': sat_selected_4, 'title': 'Saturated Image 4'},
            {'generated_image': sat_selected_5, 'title': 'Saturated Image 5'}
           ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[2][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_3_'+str(row)+str(col)+imgs_selected_list[2][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_3_'+str(row)+str(col)+imgs_selected_list[2][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(1%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[24]:
```
fig, axes = plt.subplots(nrows=7, ncols=3, figsize=(15, 15), squeeze=False)
gs = axes[0,0].get_gridspec()

current_image = cv2.imread(imgs_selected_list[3])
plt_size = gs.ncols * gs.nrows

cont_selected_1 = adjust_image_contrast(current_image, 0.5)
cont_selected_2 = adjust_image_contrast(current_image, 2.0)
cont_selected_3 = adjust_image_contrast(current_image, 1.5)
cont_selected_4 = adjust_image_contrast(current_image, 3.0)
cont_selected_5 = adjust_image_contrast(current_image, 2.5)
bright_selected_1 = adjust_image_brightness(current_image, 50)
dark_selected_1 = adjust_image_brightness(current_image, -50)
bright_selected_2 = adjust_image_brightness(current_image, 100)
```

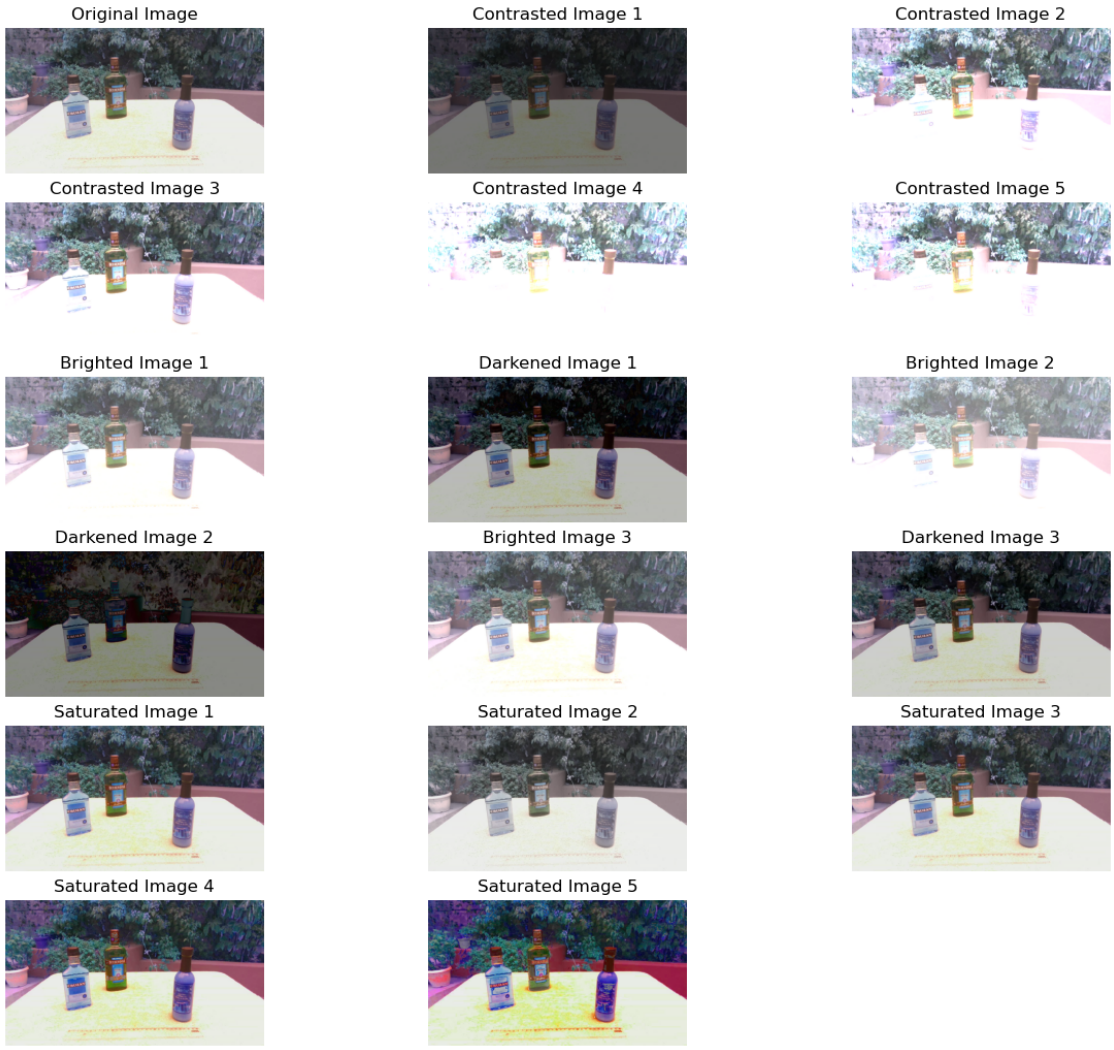
```
dark_selected_2 = adjust_image_brightness(current_image, -100)
bright_selected_3 = adjust_image_brightness(current_image, 30)
dark_selected_3 = adjust_image_brightness(current_image, -30)
sat_selected_1 = adjust_image_saturation(current_image, 1.5)
sat_selected_2 = adjust_image_saturation(current_image, 0.5)
sat_selected_3 = adjust_image_saturation(current_image, 1.2)
sat_selected_4 = adjust_image_saturation(current_image, 2.1)
sat_selected_5 = adjust_image_saturation(current_image, 3.5)

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': cont_selected_1,  'title': 'Contrasted Image␣
 ↪1'},
              {'generated_image': cont_selected_2,  'title': 'Contrasted Image␣
 ↪2'},
              {'generated_image': cont_selected_3,  'title': 'Contrasted Image␣
 ↪3'},
              {'generated_image': cont_selected_4,  'title': 'Contrasted Image␣
 ↪4'},
              {'generated_image': cont_selected_5,  'title': 'Contrasted Image␣
 ↪5'},
              {'generated_image': bright_selected_1, 'title': 'Brighted Image␣
 ↪1'},
              {'generated_image': dark_selected_1, 'title': 'Darkened Image 1'},
              {'generated_image': bright_selected_2, 'title': 'Brighted Image␣
 ↪2'},
              {'generated_image': dark_selected_2, 'title': 'Darkened Image 2'},
              {'generated_image': bright_selected_3, 'title': 'Brighted Image␣
 ↪3'},
              {'generated_image': dark_selected_3, 'title': 'Darkened Image 3'},
              {'generated_image': sat_selected_1, 'title': 'Saturated Image 1'},
              {'generated_image': sat_selected_2, 'title': 'Saturated Image 2'},
              {'generated_image': sat_selected_3, 'title': 'Saturated Image 3'},
              {'generated_image': sat_selected_4, 'title': 'Saturated Image 4'},
              {'generated_image': sat_selected_5, 'title': 'Saturated Image 5'}
             ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[3][-5:] == ".jpeg":
```

```
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_4_'+str(row)+str(col)+imgs_selected_list[3][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_4_'+str(row)+str(col)+imgs_selected_list[3][-4:],␣
 ↪f['generated_image'])


for j in range((5*3)+(1%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[25]:
```
fig, axes = plt.subplots(nrows=7, ncols=3, figsize=(15, 15), squeeze=False)
gs = axes[0,0].get_gridspec()

current_image = cv2.imread(imgs_selected_list[4])
plt_size = gs.ncols * gs.nrows

cont_selected_1 = adjust_image_contrast(current_image, 0.5)
cont_selected_2 = adjust_image_contrast(current_image, 2.0)
cont_selected_3 = adjust_image_contrast(current_image, 1.5)
cont_selected_4 = adjust_image_contrast(current_image, 3.0)
cont_selected_5 = adjust_image_contrast(current_image, 2.5)
bright_selected_1 = adjust_image_brightness(current_image, 50)
dark_selected_1 = adjust_image_brightness(current_image, -50)
bright_selected_2 = adjust_image_brightness(current_image, 100)
dark_selected_2 = adjust_image_brightness(current_image, -100)
bright_selected_3 = adjust_image_brightness(current_image, 30)
dark_selected_3 = adjust_image_brightness(current_image, -30)
sat_selected_1 = adjust_image_saturation(current_image, 1.5)
sat_selected_2 = adjust_image_saturation(current_image, 0.5)
sat_selected_3 = adjust_image_saturation(current_image, 1.2)
sat_selected_4 = adjust_image_saturation(current_image, 2.1)
sat_selected_5 = adjust_image_saturation(current_image, 3.5)

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': cont_selected_1,  'title': 'Contrasted Image␣
 ↪1'},
              {'generated_image': cont_selected_2,  'title': 'Contrasted Image␣
 ↪2'},
              {'generated_image': cont_selected_3,  'title': 'Contrasted Image␣
 ↪3'},
              {'generated_image': cont_selected_4,  'title': 'Contrasted Image␣
 ↪4'},
              {'generated_image': cont_selected_5,  'title': 'Contrasted Image␣
 ↪5'},
              {'generated_image': bright_selected_1, 'title': 'Brighted Image␣
 ↪1'},
              {'generated_image': dark_selected_1, 'title': 'Darkened Image 1'},
              {'generated_image': bright_selected_2, 'title': 'Brighted Image␣
 ↪2'},
              {'generated_image': dark_selected_2, 'title': 'Darkened Image 2'},
              {'generated_image': bright_selected_3, 'title': 'Brighted Image␣
 ↪3'},
              {'generated_image': dark_selected_3, 'title': 'Darkened Image 3'},
              {'generated_image': sat_selected_1, 'title': 'Saturated Image 1'},
              {'generated_image': sat_selected_2, 'title': 'Saturated Image 2'},
              {'generated_image': sat_selected_3, 'title': 'Saturated Image 3'},
```

```
            {'generated_image': sat_selected_4, 'title': 'Saturated Image 4'},
            {'generated_image': sat_selected_5, 'title': 'Saturated Image 5'}
           ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[4][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_5_'+str(row)+str(col)+imgs_selected_list[4][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+photo_dist_dir+'/
 ↪photo_img_5_'+str(row)+str(col)+imgs_selected_list[4][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(1%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



6 2. Geometric Distortions

6.1 Functions to do the following distortions (rotation, flipping, translation, shearing and scaling) using first principles

[26]:
```
def rotate_image_2(img, angle, center, scale):
    # Calculate rotation matrix
    rot_matrix = cv2.getRotationMatrix2D(center, angle, scale)

    # Apply affine transformation to rotate the image
    rot_image = cv2.warpAffine(img, rot_matrix, (width, height))
    return rot_image
```

[27]:
```
def flip_image_2(img, matrix, center):
    w = center[0]*2
    h = center[1]*2
    flipped_img = cv2.warpPerspective(img, matrix, (int(w), int(h)))
    return flipped_img
```

[28]:
```
def translate_image(img, matrix, center):
    w = center[0]*2
    h = center[1]*2
    translated_img = cv2.warpAffine(img, matrix, (int(w), int(h)))
    return translated_img
```

[29]:
```
def shear_image(img, matrix, center):
    w = center[0]*2
    h = center[1]*2
    sheared_img = cv2.warpPerspective(img, matrix, (int(w*1.5), int(h*1.5)))
    return sheared_img
```

[30]:
```
def scale_image(img, matrix, center):
    w = center[0]*2
    h = center[1]*2
    sheared_img = cv2.warpPerspective(img, matrix, (int(w), int(h)))
    return sheared_img
```

[31]:
```
img_selected.shape
```

[31]:
```
(720, 1280, 3)
```

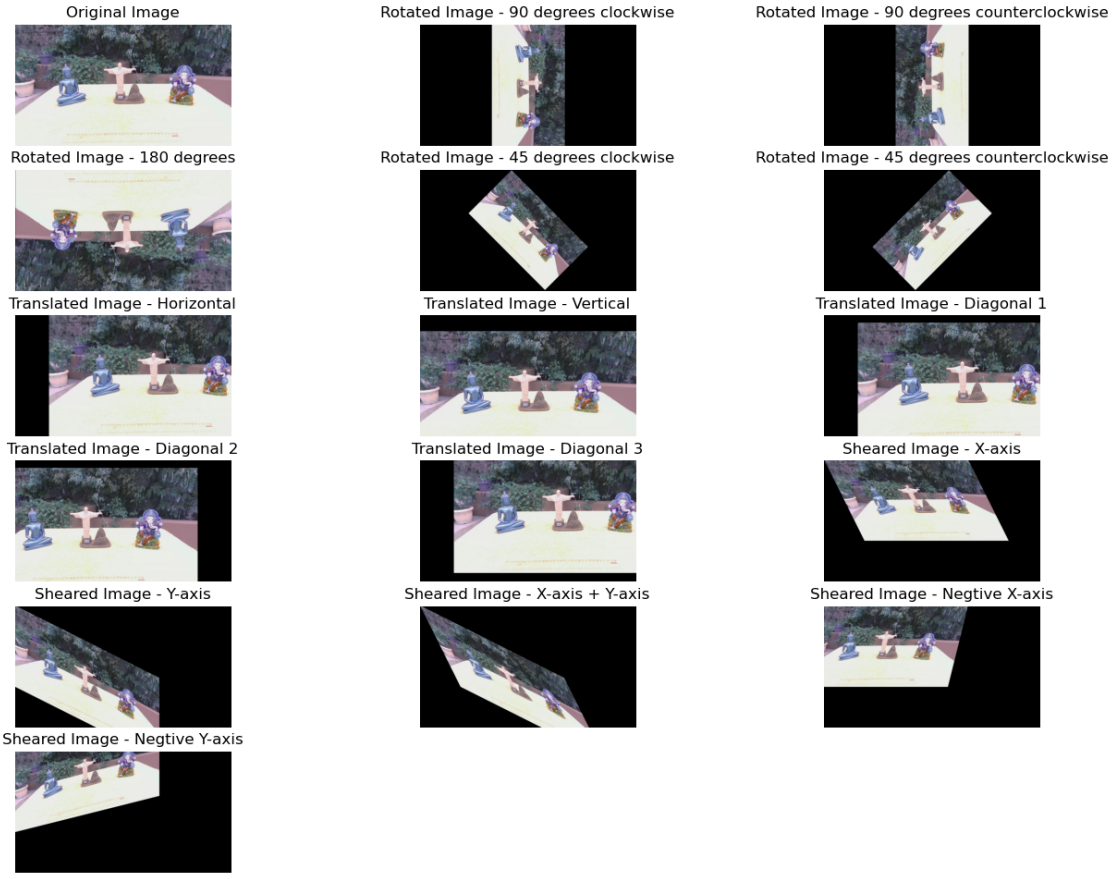
6.2 Applying three of the five distortions above (rotation, translation and shearing) to the selected images and displaying them in order

Image flipping and scaling were not applied as a maximum of three images could be generated using each technique.

[32]:
```
fig, axes = plt.subplots(nrows=8, ncols=3, figsize=(16, 16), squeeze=False)

current_image = cv2.imread(imgs_selected_list[0])

rot_selected_90_c = rotate_image_2(current_image, -90, center, 0.6)
rot_selected_90_cc = rotate_image_2(current_image, 90, center, 0.6)
rot_selected_180 = rotate_image_2(current_image, 180, center, 1)
rot_selected_45_c = rotate_image_2(current_image, -45, center, 0.5)
rot_selected_45_cc = rotate_image_2(current_image, 45, center, 0.5)
trans_selected_hor = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,0]]), center)
trans_selected_ver = translate_image(current_image, np.
 ↪float32([[1,0,0],[0,1,100]]), center)
```

```
trans_selected_diag_1 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,50]]), center)
trans_selected_diag_2 = translate_image(current_image, np.
 ↪float32([[1,0,-200],[0,1,50]]), center)
trans_selected_diag_3 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,-50]]), center)
shear_selected_x = shear_image(current_image, np.float32([[1, 0.5, 0], [0, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_y = shear_image(current_image, np.float32([[1, 0, 0], [0.5, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_x_y = shear_image(current_image, np.float32([[1, 0.5, 0], [0.5,␣
 ↪1, 0], [0, 0, 1]]), center)
shear_selected_x_neg = shear_image(current_image, np.float32([[1, -0.25, 0],␣
 ↪[0, 1, 0], [0, 0, 1]]), center)
shear_selected_y_neg = shear_image(current_image, np.float32([[1, 0, 0], [-0.
 ↪25, 1, 0], [0, 0, 1]]), center)

gs = axes[0,0].get_gridspec()
plt_size = gs.ncols * gs.nrows

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': rot_selected_90_c,  'title': 'Rotated Image -␣
 ↪90 degrees clockwise'},
              {'generated_image': rot_selected_90_cc,  'title': 'Rotated Image␣
 ↪- 90 degrees counterclockwise'},
              {'generated_image': rot_selected_180,  'title': 'Rotated Image -␣
 ↪180 degrees'},
              {'generated_image': rot_selected_45_c,  'title': 'Rotated Image -␣
 ↪45 degrees clockwise'},
              {'generated_image': rot_selected_45_cc,  'title': 'Rotated Image␣
 ↪- 45 degrees counterclockwise'},
              {'generated_image': trans_selected_hor, 'title': 'Translated␣
 ↪Image - Horizontal'},
              {'generated_image': trans_selected_ver, 'title': 'Translated␣
 ↪Image - Vertical'},
              {'generated_image': trans_selected_diag_1, 'title': 'Translated␣
 ↪Image - Diagonal 1'},
              {'generated_image': trans_selected_diag_2, 'title': 'Translated␣
 ↪Image - Diagonal 2'},
              {'generated_image': trans_selected_diag_3, 'title': 'Translated␣
 ↪Image - Diagonal 3'},
              {'generated_image': shear_selected_x, 'title': 'Sheared Image -␣
 ↪X-axis'},
              {'generated_image': shear_selected_y, 'title': 'Sheared Image -␣
 ↪Y-axis'},
```

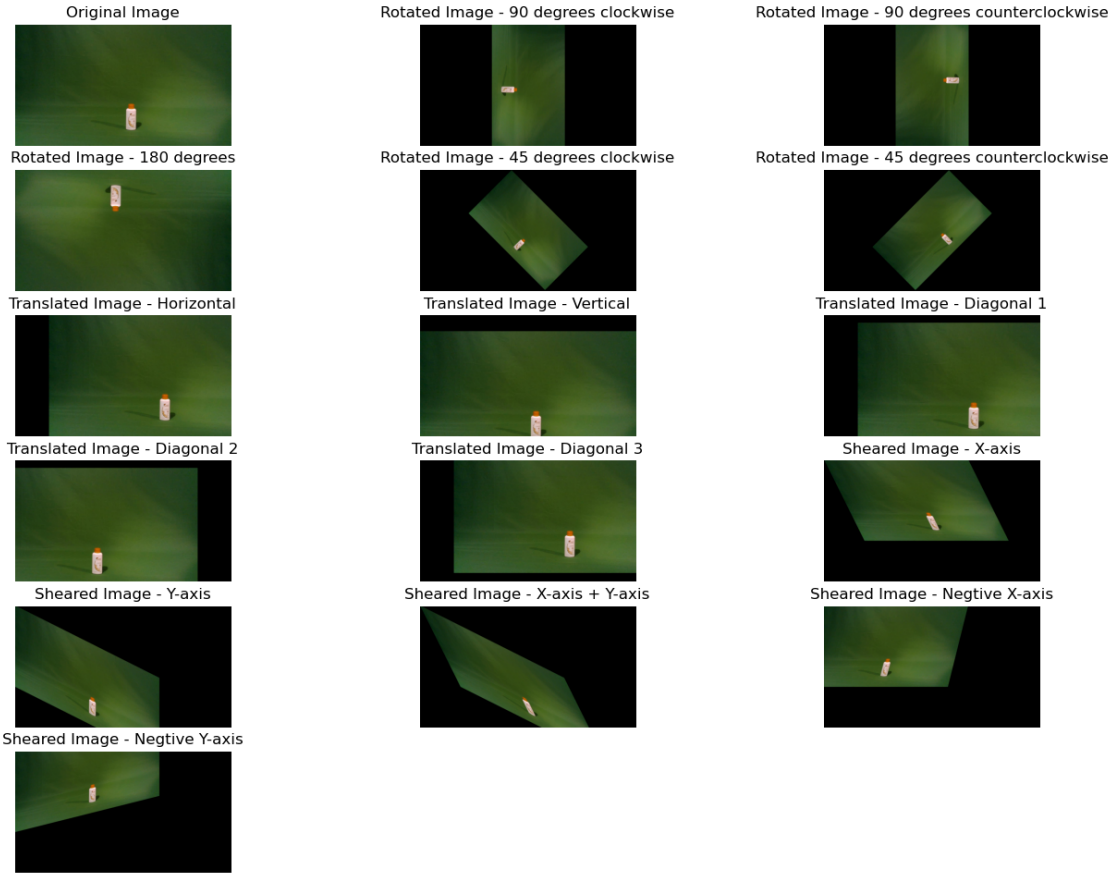
```
            {'generated_image': shear_selected_x_y, 'title': 'Sheared Image -␣
 ↪X-axis + Y-axis'},
            {'generated_image': shear_selected_x_neg, 'title': 'Sheared Image␣
 ↪- Negtive X-axis'},
            {'generated_image': shear_selected_y_neg, 'title': 'Sheared Image␣
 ↪- Negtive Y-axis'},
            ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[0][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_1_'+str(row)+str(col)+imgs_selected_list[0][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_1_'+str(row)+str(col)+imgs_selected_list[0][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(0%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[33]:
```
fig, axes = plt.subplots(nrows=8, ncols=3, figsize=(16, 16), squeeze=False)

current_image = cv2.imread(imgs_selected_list[1])

rot_selected_90_c = rotate_image_2(current_image, -90, center, 0.6)
rot_selected_90_cc = rotate_image_2(current_image, 90, center, 0.6)
rot_selected_180 = rotate_image_2(current_image, 180, center, 1)
rot_selected_45_c = rotate_image_2(current_image, -45, center, 0.5)
rot_selected_45_cc = rotate_image_2(current_image, 45, center, 0.5)
trans_selected_hor = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,0]]), center)
trans_selected_ver = translate_image(current_image, np.
 ↪float32([[1,0,0],[0,1,100]]), center)
trans_selected_diag_1 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,50]]), center)
trans_selected_diag_2 = translate_image(current_image, np.
 ↪float32([[1,0,-200],[0,1,50]]), center)
trans_selected_diag_3 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,-50]]), center)
```

```
shear_selected_x = shear_image(current_image, np.float32([[1, 0.5, 0], [0, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_y = shear_image(current_image, np.float32([[1, 0, 0], [0.5, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_x_y = shear_image(current_image, np.float32([[1, 0.5, 0], [0.5,␣
 ↪1, 0], [0, 0, 1]]), center)
shear_selected_x_neg = shear_image(current_image, np.float32([[1, -0.25, 0],␣
 ↪[0, 1, 0], [0, 0, 1]]), center)
shear_selected_y_neg = shear_image(current_image, np.float32([[1, 0, 0], [-0.
 ↪25, 1, 0], [0, 0, 1]]), center)

gs = axes[0,0].get_gridspec()
plt_size = gs.ncols * gs.nrows

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': rot_selected_90_c,  'title': 'Rotated Image -␣
 ↪90 degrees clockwise'},
              {'generated_image': rot_selected_90_cc,  'title': 'Rotated Image␣
 ↪- 90 degrees counterclockwise'},
              {'generated_image': rot_selected_180,  'title': 'Rotated Image -␣
 ↪180 degrees'},
              {'generated_image': rot_selected_45_c,  'title': 'Rotated Image -␣
 ↪45 degrees clockwise'},
              {'generated_image': rot_selected_45_cc,  'title': 'Rotated Image␣
 ↪- 45 degrees counterclockwise'},
              {'generated_image': trans_selected_hor, 'title': 'Translated␣
 ↪Image - Horizontal'},
              {'generated_image': trans_selected_ver, 'title': 'Translated␣
 ↪Image - Vertical'},
              {'generated_image': trans_selected_diag_1, 'title': 'Translated␣
 ↪Image - Diagonal 1'},
              {'generated_image': trans_selected_diag_2, 'title': 'Translated␣
 ↪Image - Diagonal 2'},
              {'generated_image': trans_selected_diag_3, 'title': 'Translated␣
 ↪Image - Diagonal 3'},
              {'generated_image': shear_selected_x, 'title': 'Sheared Image -␣
 ↪X-axis'},
              {'generated_image': shear_selected_y, 'title': 'Sheared Image -␣
 ↪Y-axis'},
              {'generated_image': shear_selected_x_y, 'title': 'Sheared Image -␣
 ↪X-axis + Y-axis'},
              {'generated_image': shear_selected_x_neg, 'title': 'Sheared Image␣
 ↪- Negtive X-axis'},
              {'generated_image': shear_selected_y_neg, 'title': 'Sheared Image␣
 ↪- Negtive Y-axis'},
```

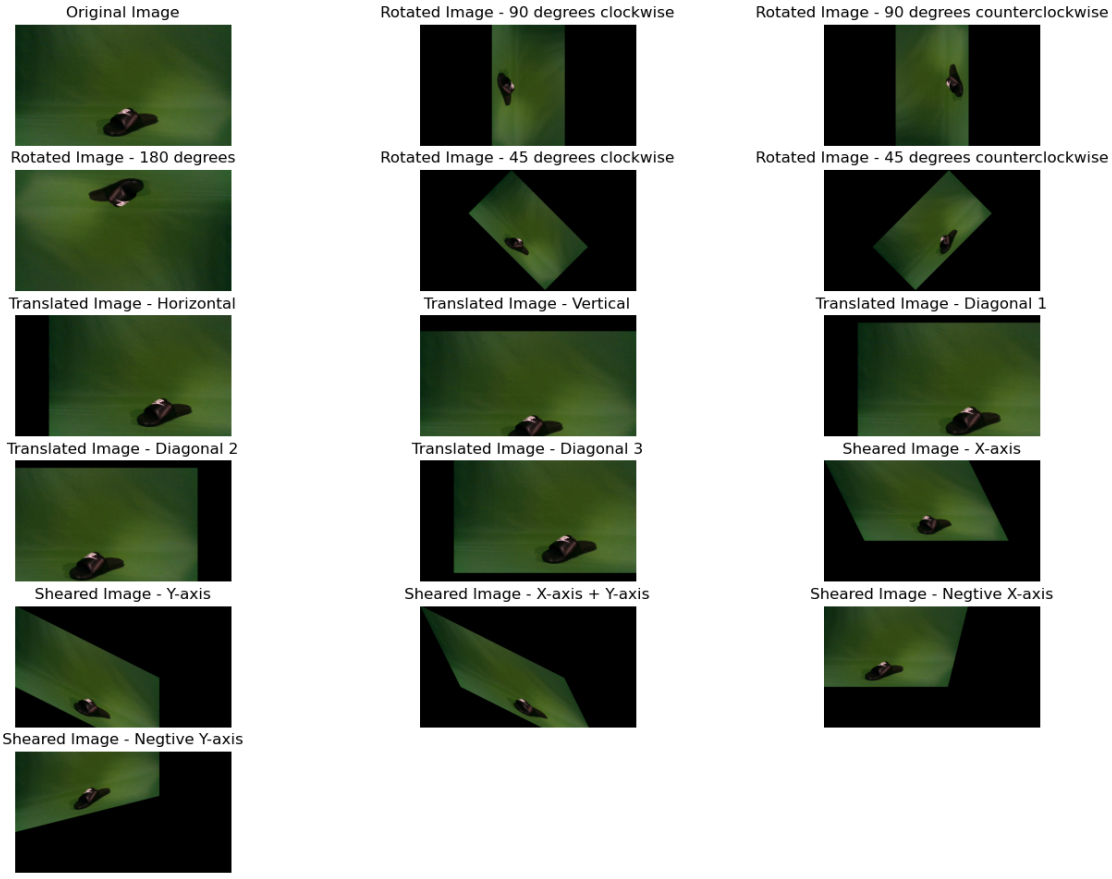
```
            ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[1][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_2_'+str(row)+str(col)+imgs_selected_list[1][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_2_'+str(row)+str(col)+imgs_selected_list[1][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(0%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[34]:
```
fig, axes = plt.subplots(nrows=8, ncols=3, figsize=(16, 16), squeeze=False)

current_image = cv2.imread(imgs_selected_list[2])

rot_selected_90_c = rotate_image_2(current_image, -90, center, 0.6)
rot_selected_90_cc = rotate_image_2(current_image, 90, center, 0.6)
rot_selected_180 = rotate_image_2(current_image, 180, center, 1)
rot_selected_45_c = rotate_image_2(current_image, -45, center, 0.5)
rot_selected_45_cc = rotate_image_2(current_image, 45, center, 0.5)
trans_selected_hor = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,0]]), center)
trans_selected_ver = translate_image(current_image, np.
 ↪float32([[1,0,0],[0,1,100]]), center)
trans_selected_diag_1 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,50]]), center)
trans_selected_diag_2 = translate_image(current_image, np.
 ↪float32([[1,0,-200],[0,1,50]]), center)
trans_selected_diag_3 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,-50]]), center)
```

```
shear_selected_x = shear_image(current_image, np.float32([[1, 0.5, 0], [0, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_y = shear_image(current_image, np.float32([[1, 0, 0], [0.5, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_x_y = shear_image(current_image, np.float32([[1, 0.5, 0], [0.5,␣
 ↪1, 0], [0, 0, 1]]), center)
shear_selected_x_neg = shear_image(current_image, np.float32([[1, -0.25, 0],␣
 ↪[0, 1, 0], [0, 0, 1]]), center)
shear_selected_y_neg = shear_image(current_image, np.float32([[1, 0, 0], [-0.
 ↪25, 1, 0], [0, 0, 1]]), center)

gs = axes[0,0].get_gridspec()
plt_size = gs.ncols * gs.nrows

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': rot_selected_90_c,  'title': 'Rotated Image -␣
 ↪90 degrees clockwise'},
              {'generated_image': rot_selected_90_cc,  'title': 'Rotated Image␣
 ↪- 90 degrees counterclockwise'},
              {'generated_image': rot_selected_180,  'title': 'Rotated Image -␣
 ↪180 degrees'},
              {'generated_image': rot_selected_45_c,  'title': 'Rotated Image -␣
 ↪45 degrees clockwise'},
              {'generated_image': rot_selected_45_cc,  'title': 'Rotated Image␣
 ↪- 45 degrees counterclockwise'},
              {'generated_image': trans_selected_hor, 'title': 'Translated␣
 ↪Image - Horizontal'},
              {'generated_image': trans_selected_ver, 'title': 'Translated␣
 ↪Image - Vertical'},
              {'generated_image': trans_selected_diag_1, 'title': 'Translated␣
 ↪Image - Diagonal 1'},
              {'generated_image': trans_selected_diag_2, 'title': 'Translated␣
 ↪Image - Diagonal 2'},
              {'generated_image': trans_selected_diag_3, 'title': 'Translated␣
 ↪Image - Diagonal 3'},
              {'generated_image': shear_selected_x, 'title': 'Sheared Image -␣
 ↪X-axis'},
              {'generated_image': shear_selected_y, 'title': 'Sheared Image -␣
 ↪Y-axis'},
              {'generated_image': shear_selected_x_y, 'title': 'Sheared Image -␣
 ↪X-axis + Y-axis'},
              {'generated_image': shear_selected_x_neg, 'title': 'Sheared Image␣
 ↪- Negtive X-axis'},
              {'generated_image': shear_selected_y_neg, 'title': 'Sheared Image␣
 ↪- Negtive Y-axis'},
```

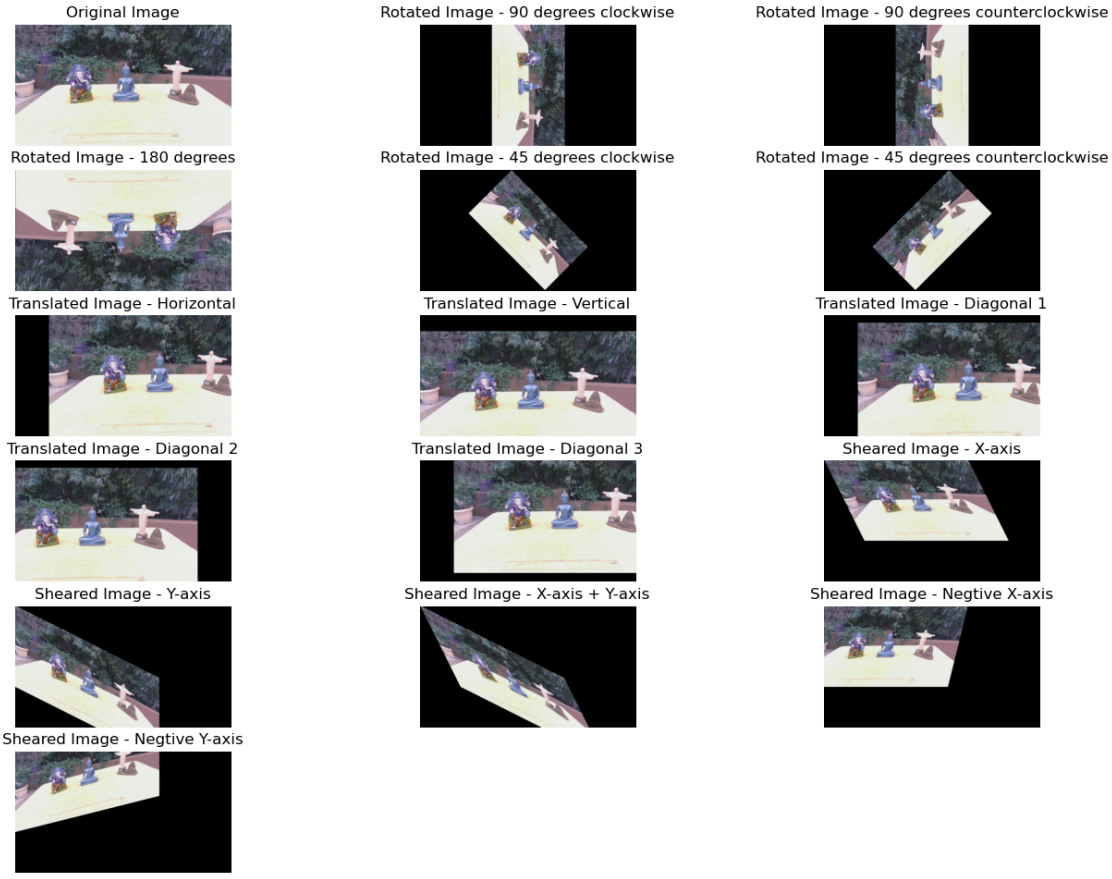
```
            ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[2][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_3_'+str(row)+str(col)+imgs_selected_list[2][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_3_'+str(row)+str(col)+imgs_selected_list[2][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(0%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[35]:
```
fig, axes = plt.subplots(nrows=8, ncols=3, figsize=(16, 16), squeeze=False)

current_image = cv2.imread(imgs_selected_list[3])

rot_selected_90_c = rotate_image_2(current_image, -90, center, 0.6)
rot_selected_90_cc = rotate_image_2(current_image, 90, center, 0.6)
rot_selected_180 = rotate_image_2(current_image, 180, center, 1)
rot_selected_45_c = rotate_image_2(current_image, -45, center, 0.5)
rot_selected_45_cc = rotate_image_2(current_image, 45, center, 0.5)
trans_selected_hor = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,0]]), center)
trans_selected_ver = translate_image(current_image, np.
 ↪float32([[1,0,0],[0,1,100]]), center)
trans_selected_diag_1 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,50]]), center)
trans_selected_diag_2 = translate_image(current_image, np.
 ↪float32([[1,0,-200],[0,1,50]]), center)
trans_selected_diag_3 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,-50]]), center)
```

```
shear_selected_x = shear_image(current_image, np.float32([[1, 0.5, 0], [0, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_y = shear_image(current_image, np.float32([[1, 0, 0], [0.5, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_x_y = shear_image(current_image, np.float32([[1, 0.5, 0], [0.5,␣
 ↪1, 0], [0, 0, 1]]), center)
shear_selected_x_neg = shear_image(current_image, np.float32([[1, -0.25, 0],␣
 ↪[0, 1, 0], [0, 0, 1]]), center)
shear_selected_y_neg = shear_image(current_image, np.float32([[1, 0, 0], [-0.
 ↪25, 1, 0], [0, 0, 1]]), center)

gs = axes[0,0].get_gridspec()
plt_size = gs.ncols * gs.nrows

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': rot_selected_90_c,  'title': 'Rotated Image -␣
 ↪90 degrees clockwise'},
              {'generated_image': rot_selected_90_cc,  'title': 'Rotated Image␣
 ↪- 90 degrees counterclockwise'},
              {'generated_image': rot_selected_180,  'title': 'Rotated Image -␣
 ↪180 degrees'},
              {'generated_image': rot_selected_45_c,  'title': 'Rotated Image -␣
 ↪45 degrees clockwise'},
              {'generated_image': rot_selected_45_cc,  'title': 'Rotated Image␣
 ↪- 45 degrees counterclockwise'},
              {'generated_image': trans_selected_hor, 'title': 'Translated␣
 ↪Image - Horizontal'},
              {'generated_image': trans_selected_ver, 'title': 'Translated␣
 ↪Image - Vertical'},
              {'generated_image': trans_selected_diag_1, 'title': 'Translated␣
 ↪Image - Diagonal 1'},
              {'generated_image': trans_selected_diag_2, 'title': 'Translated␣
 ↪Image - Diagonal 2'},
              {'generated_image': trans_selected_diag_3, 'title': 'Translated␣
 ↪Image - Diagonal 3'},
              {'generated_image': shear_selected_x, 'title': 'Sheared Image -␣
 ↪X-axis'},
              {'generated_image': shear_selected_y, 'title': 'Sheared Image -␣
 ↪Y-axis'},
              {'generated_image': shear_selected_x_y, 'title': 'Sheared Image -␣
 ↪X-axis + Y-axis'},
              {'generated_image': shear_selected_x_neg, 'title': 'Sheared Image␣
 ↪- Negtive X-axis'},
              {'generated_image': shear_selected_y_neg, 'title': 'Sheared Image␣
 ↪- Negtive Y-axis'},
```

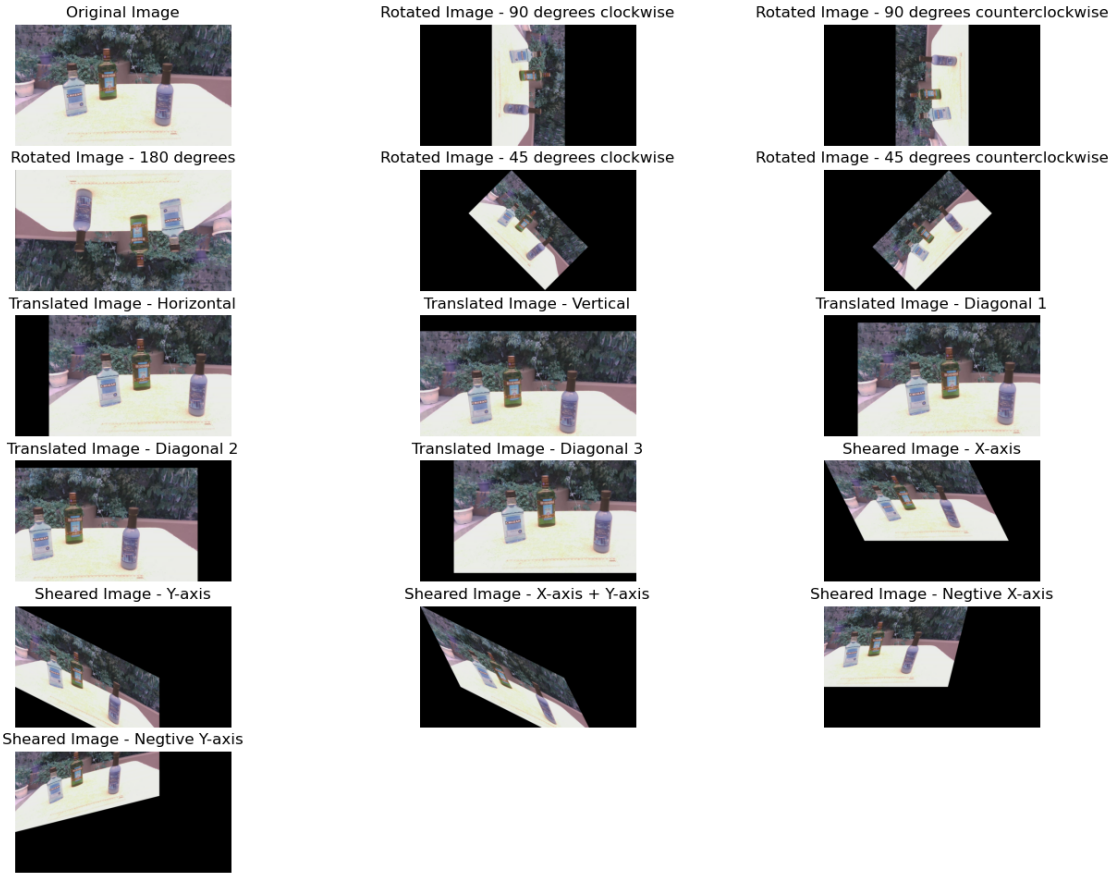
```
            ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[3][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_4_'+str(row)+str(col)+imgs_selected_list[3][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_4_'+str(row)+str(col)+imgs_selected_list[3][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(0%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```



[36]:
```
fig, axes = plt.subplots(nrows=8, ncols=3, figsize=(16, 16), squeeze=False)

current_image = cv2.imread(imgs_selected_list[4])

rot_selected_90_c = rotate_image_2(current_image, -90, center, 0.6)
rot_selected_90_cc = rotate_image_2(current_image, 90, center, 0.6)
rot_selected_180 = rotate_image_2(current_image, 180, center, 1)
rot_selected_45_c = rotate_image_2(current_image, -45, center, 0.5)
rot_selected_45_cc = rotate_image_2(current_image, 45, center, 0.5)
trans_selected_hor = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,0]]), center)
trans_selected_ver = translate_image(current_image, np.
 ↪float32([[1,0,0],[0,1,100]]), center)
trans_selected_diag_1 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,50]]), center)
trans_selected_diag_2 = translate_image(current_image, np.
 ↪float32([[1,0,-200],[0,1,50]]), center)
trans_selected_diag_3 = translate_image(current_image, np.
 ↪float32([[1,0,200],[0,1,-50]]), center)
```

```
shear_selected_x = shear_image(current_image, np.float32([[1, 0.5, 0], [0, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_y = shear_image(current_image, np.float32([[1, 0, 0], [0.5, 1,␣
 ↪0], [0, 0, 1]]), center)
shear_selected_x_y = shear_image(current_image, np.float32([[1, 0.5, 0], [0.5,␣
 ↪1, 0], [0, 0, 1]]), center)
shear_selected_x_neg = shear_image(current_image, np.float32([[1, -0.25, 0],␣
 ↪[0, 1, 0], [0, 0, 1]]), center)
shear_selected_y_neg = shear_image(current_image, np.float32([[1, 0, 0], [-0.
 ↪25, 1, 0], [0, 0, 1]]), center)

gs = axes[0,0].get_gridspec()
plt_size = gs.ncols * gs.nrows

aug_images = [{'generated_image': current_image, 'title': 'Original Image'},
              {'generated_image': rot_selected_90_c,  'title': 'Rotated Image -␣
 ↪90 degrees clockwise'},
              {'generated_image': rot_selected_90_cc,  'title': 'Rotated Image␣
 ↪- 90 degrees counterclockwise'},
              {'generated_image': rot_selected_180,  'title': 'Rotated Image -␣
 ↪180 degrees'},
              {'generated_image': rot_selected_45_c,  'title': 'Rotated Image -␣
 ↪45 degrees clockwise'},
              {'generated_image': rot_selected_45_cc,  'title': 'Rotated Image␣
 ↪- 45 degrees counterclockwise'},
              {'generated_image': trans_selected_hor, 'title': 'Translated␣
 ↪Image - Horizontal'},
              {'generated_image': trans_selected_ver, 'title': 'Translated␣
 ↪Image - Vertical'},
              {'generated_image': trans_selected_diag_1, 'title': 'Translated␣
 ↪Image - Diagonal 1'},
              {'generated_image': trans_selected_diag_2, 'title': 'Translated␣
 ↪Image - Diagonal 2'},
              {'generated_image': trans_selected_diag_3, 'title': 'Translated␣
 ↪Image - Diagonal 3'},
              {'generated_image': shear_selected_x, 'title': 'Sheared Image -␣
 ↪X-axis'},
              {'generated_image': shear_selected_y, 'title': 'Sheared Image -␣
 ↪Y-axis'},
              {'generated_image': shear_selected_x_y, 'title': 'Sheared Image -␣
 ↪X-axis + Y-axis'},
              {'generated_image': shear_selected_x_neg, 'title': 'Sheared Image␣
 ↪- Negtive X-axis'},
              {'generated_image': shear_selected_y_neg, 'title': 'Sheared Image␣
 ↪- Negtive Y-axis'},
```

```
            ]

for i, f in enumerate(aug_images):
    row = (i) // gs.ncols
    col = (i) % gs.ncols
    axes[row, col].imshow(f['generated_image'], cmap='gray')
    axes[row, col].set_title(f['title'])
    axes[row, col].axis('off')
    # Saving the augmented images in local storage
    if f['title'] != 'Original Image':
        if imgs_selected_list[4][-5:] == ".jpeg":
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_5_'+str(row)+str(col)+imgs_selected_list[4][-5:],␣
 ↪f['generated_image'])
        else:
            cv2.imwrite(saved_imgs_dir+'/'+geo_dist_dir+'/
 ↪photo_img_5_'+str(row)+str(col)+imgs_selected_list[4][-4:],␣
 ↪f['generated_image'])

for j in range((5*3)+(0%3), plt_size-1):
    #print(j)
    row = (j+1) // gs.ncols
    col = (j+1) % gs.ncols
    axes[row, col].set_visible(False)
```


Original Image
Rotated Image - 90 degrees clockwise
Rotated Image - 90 degrees counterclockwise
Rotated Image - 180 degrees
Rotated Image - 45 degrees clockwise
Rotated Image - 45 degrees counterclockwise
Translated Image - Horizontal
Translated Image - Vertical
Translated Image - Diagonal 1
Translated Image - Diagonal 2
Translated Image - Diagonal 3
Sheared Image - X-axis
Sheared Image - Y-axis
Sheared Image - X-axis + Y-axis
Sheared Image - Negtive X-axis
Sheared Image - Negtive Y-axis

[ ]: