EE5178: Panoramic Stitching

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MM19B022

Brief Overview

In this problem set, you will implement panoramic stitching. Given two input images, we will "stitch" them together to create a simple panorama. To construct the image panorama, we will use concepts learned in class such as keypoint detection, local invariant descriptors, RANSAC, and perspective warping.

The panoramic stitching algorithm consists of four main steps which we ask you to implement in individual functions:

1. Detect keypoints and extract local invariant descriptors from two input images.
2. Match the descriptors between the two images.
3. Apply RANSAC to estimate a homography matrix between the extracted features.
4. Apply a perspective transformation using the homography matrix to merge image into a panorama.

Functions to implement (refer to function comments for more detail):

1. get_features
2. match_keypoints
3. find_homography and transform_ransac
4. panoramic_stitching

Starting

Run the following code to import the modules you'll need. After your finish the assignment, remember to run all cells and save the note book to your local machine as a .ipynb file for Canvas submission.

```
%matplotlib inline
import cv2
import random
import numpy as np
```

```
import matplotlib.pyplot as plt
from google.colab.patches import cv2_imshow
import numpy.ma as ma


%%capture
! wget -O img1.jpg "https://drive.google.com/uc?export=download&id=1omMydL6ADxq_vW5
! wget -O img2.jpg "https://drive.google.com/uc?export=download&id=12lxB1ArAlwGn97Z
```

Visualize Input Images

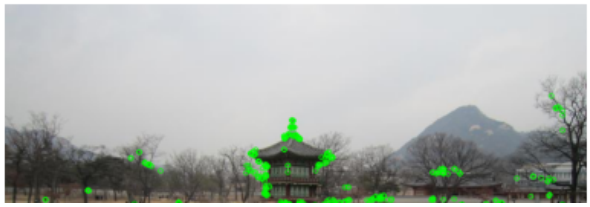
```
img1 = plt.imread('img1.jpg')
img2 = plt.imread('img2.jpg')

def plot_imgs(img1, img2):
  fig, ax = plt.subplots(1, 2, figsize=(15, 20))
  for a in ax:
    a.set_axis_off()
  ax[0].imshow(img1)
  ax[1].imshow(img2)

plot_imgs(img1, img2)
```

Compute SURF/ SIFT/ ORB Features and Match Keypoints

```
def get_features(img):
  '''
    Compute SURF/SIFT/ORB features using cv2 library functions. Use default paramet
    Input:
      img: cv2 image
    Returns:
      keypoints: a list of cv2 keypoints
```

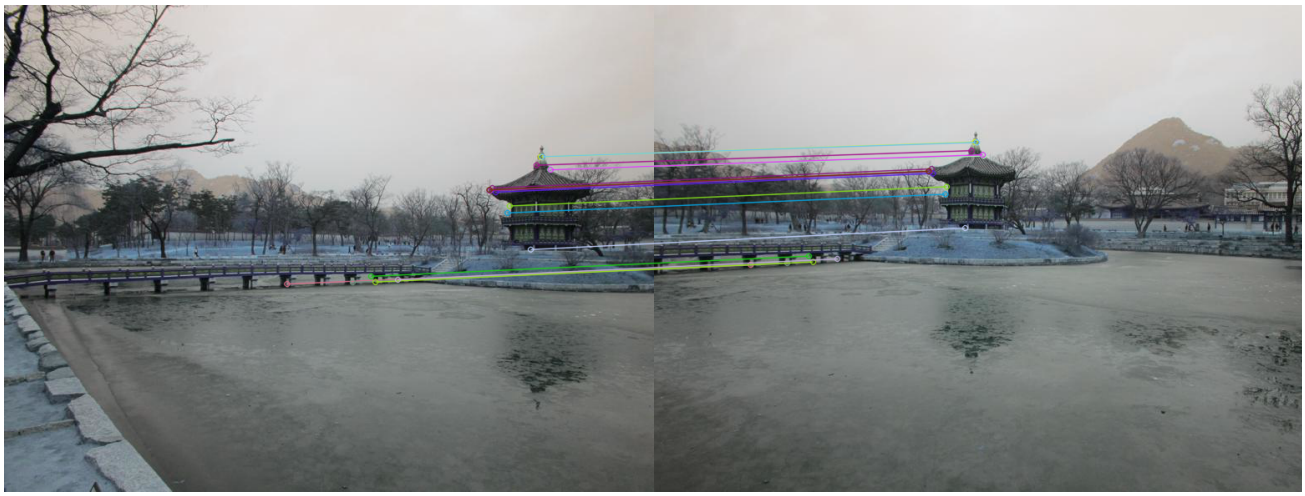
```
      descriptors: a list of feature descriptors
    '''
    # ================================================
    # TODO
    # ================================================
    orb = cv2.ORB_create()
    keypoints, descriptors = orb.detectAndCompute(img,None)
    return keypoints, descriptors

def match_keypoints(desc_1, desc_2, ratio=0.75):
    '''
      You may use cv2 library functions.
      Input:
        desc_1, desc_2: list of feature descriptors
      Return:
        matches: list of feature matches
    '''
    # ================================================
    # TODO
    # ================================================
    bf = cv2.BFMatcher()
    matches = bf.knnMatch(desc_1, desc_2, k=2)

    good = []
    for m,n in matches:
      if m.distance < 0.75*n.distance:
        good.append([m])

    good = sorted(good, key = lambda x : x[0].distance)



    return good


kp_1, desc_1 = get_features(img1)
kp_2, desc_2 = get_features(img2)

kp_img1 = cv2.drawKeypoints(img1, kp_1, None, color=(0,255,0), flags=0)
kp_img2 = cv2.drawKeypoints(img2, kp_2, None, color=(0,255,0), flags=0)

print('keypoints for img1 and img2')
plot_imgs(kp_img1, kp_img2)
```

keypoints for img1 and img2



```
matches = match_keypoints(desc_1, desc_2)[:20]

match_plot = cv2.drawMatchesKnn(img1, kp_1, img2, kp_2, matches, None, flags=2)
print("feature matches")
cv2_imshow(match_plot)
```

feature matches



Compute Homography Matrix using RANSAC

```
def find_homography(pts_1, pts_2):
  '''
    Implement Direct Linear Transform to find a homography that estimates the trans
    e.g. If x is in pts_1 and y is in pts_2, then y = H * x
    Input:
      pts_1, pts_1: (N, 2) matrix
    Return:
      H: the resultant homography matrix (3 x 3)
  '''
  # ================================================
  # TODO
  # ================================================
  n = np.shape(pts_1)[0]
  #print(pts_1)
```

```
  pts_1 = np.array(pts_1)
  pts_2 = np.array(pts_2)
  pts_1t = np.transpose(pts_1)
  pts_2t = np.transpose(pts_2)

  x_s, y_s = np.transpose(pts_1t[0][:]), np.transpose(pts_1t[1][:])
  x_t, y_t = np.transpose(pts_2t[0][:]), np.transpose(pts_2t[1][:])

  z_s = z_t = np.ones((n,1))
  #m = np.shape(x_s)[0]
  #print(x_t)

  A = []

  for i in range(n):
    temp = np.array([[0, 0, 0, -z_t[i]*x_s[i], -z_t[i]*y_s[i], -z_t[i]*z_s[i], y_t[
                     [z_t[i]*x_s[i], z_t[i]*y_s[i], z_t[i]*z_s[i], 0, 0, 0, -x_t[i]
    A.append(temp)

  A = np.concatenate(A, axis = 0)
  #print(A)
  A = np.array(A, dtype = 'float64')
  #print(A.shape)
  u, s, v = np.linalg.svd(A, full_matrices = True)
  #print((v[-1]).shape)
  H = v[-1].reshape((3,3))
  H = H/H[2,2]

  return H

from numpy.linalg.linalg import zeros

def transform_ransac(pts_1, pts_2):
  '''
    Implement RANSAC to estimate homography matrix.
    Input:
      pts_1, pts_1: (N, 2) matrices
    Return:
      best_model: homography matrix with most inliers
  '''
  # ================================================
  # TODO
  # ================================================
  N = len(pts_1)
  iter = 2999
  z = [1 for i in range(N)]
  e = 10
  best_in = 0

  pts_in = []
  x_sub = []
  y_sub = []

  pts1n=[]
  pts2n=[]
```

```
  for i in pts_1:
    pts1n.append(list(i)+[1])
  for i in pts_2:
    pts2n.append(list(i)+[1])
  pts_1=np.array(pts1n)
  pts_2=np.array(pts2n)
  print(pts_1.shape)

  for i in range(iter):
    indices = random.sample(range(0, N-1), 4)
    sub_1 = []
    sub_2 = []
    for j in range(0, 4):
      sub_1.append(pts_1[indices[j]])
      sub_2.append(pts_2[indices[j]])

    H = find_homography(sub_1, sub_2)
    '''
    pts_1t=np.transpose(np.array(pts_1))
    pts_2t=np.transpose(np.array(pts_2))
    zt=np.transpose(z)
    pts_1t=np.concatenate(pts_1t,zt)
    pts_2t=np.concatenate(pts_2t,zt)
    '''

    pts_2_pred = np.matmul(pts_1, H)
    diff = pts_2 - pts_2_pred

    mask = diff < e
    diff_in = ma.masked_array(diff, mask)
    pt1 = ma.masked_array(pts_1, mask)
    pt2 = ma.masked_array(pts_2, mask)

    n_in = len(diff_in)

    if n_in>best_in:
      best_in = n_in
      best_subset_x = pt1
      best_subset_y = pt2

  best_model = find_homography(best_subset_x, best_subset_y)

  return best_model
```

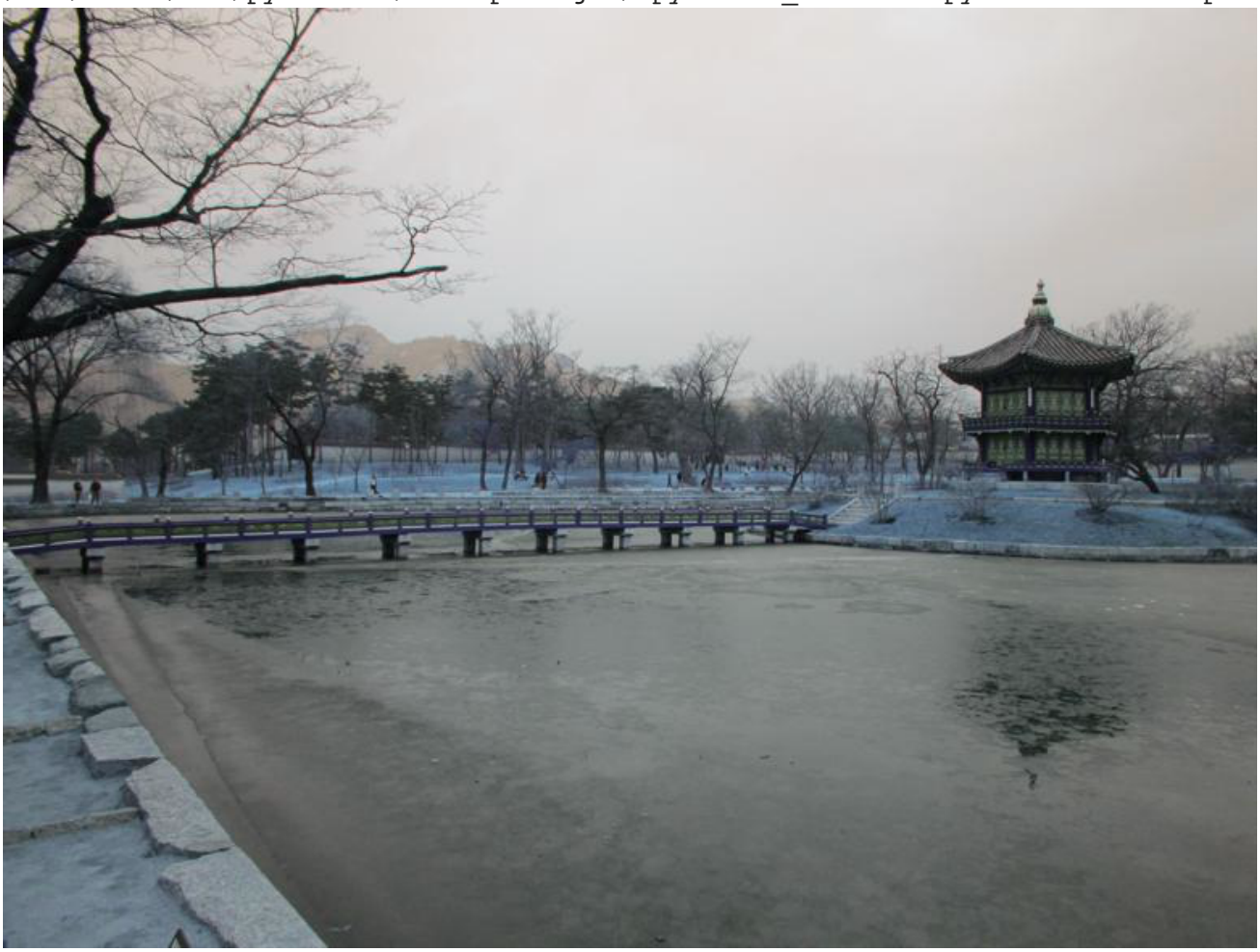
Panoramic Stitching

```
def panoramic_stitching(img1, img2):
  '''
    Generate a panoramic image using the obtained homography matrix.
    Input:
      img1, img2: cv2 images
```

```
  Return:
    final_img: cv2 image of panorama
'''
# ================================================
# TODO
# ================================================
kp_1, desc_1 = get_features(img1)
kp_2, desc_2 = get_features(img2)

kp_img1 = cv2.drawKeypoints(img1, kp_1, None, color=(0,255,0), flags=0)
kp_img2 = cv2.drawKeypoints(img2, kp_2, None, color=(0,255,0), flags=0)
matches = match_keypoints(desc_1, desc_2)

pts_1 = []
pts_2 = []
for m in matches:
  m = m[0]
  p1 = kp_1[m.queryIdx].pt
  p2 = kp_2[m.trainIdx].pt
  pts_1.append(p1)
  pts_2.append(p2)

H = transform_ransac(pts_2, pts_1)
H_inv = np.linalg.inv(H)

xmax = 0
ymax = 0

for x in [0, img2.shape[1]-1]:
  for y in [0, img2.shape[0]-1]:
    point = np.array([x, y, 1])
    t_point = np.matmul(H, point)
    t_point = t_point/t_point[2]
    tx, ty = t_point[0], t_point[1]

    if tx>xmax:
      txmax = tx
    if ty>ymax:
      tymax = ty

tymax = int(tymax)
txmax = int(txmax)
final_img = np.zeros([max(tymax, img1.shape[0]), max(txmax, img1.shape[1]), img2.

for i in range(max(tymax, img1.shape[0])):
  for j in range(max(txmax, img1.shape[1])):
    point = np.array([j, i, 1])
    og_point = np.matmul(H_inv, point)
    og_point = og_point/og_point[2]
    x, y = og_point[0], og_point[1]
    x = int(x)
    y = int(y)
    if x>=0 and x<np.shape(img2)[1] and y>=0 and y<np.shape(img2)[0]:
      final_img[i, j, :] = img2[y, x, :]
```

```
  final_img[0:img1.shape[0], 0:img1.shape[1]] = img1


  return final_img

result = panoramic_stitching(img1, img2)
cv2_imshow(result)
```

```
(53, 3)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:31: VisibleDeprec
```



The 3 image problem

```
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Mounted at /content/gdrive
```

```
%%capture
```

```
! wget -O img_1.jpg "https://drive.google.com/file/d/1Iw-KBQyujaNesg4aebrxwsSIef-cI
! wget -O img_2.jpg "https://drive.google.com/file/d/1d0ZUAqljLMPrd8RjrEAgbJ4tA-2bY
! wget -O img_3.jpg "https://drive.google.com/file/d/1TN248Jus2K8h8Alcaz2ez7YUrJJTX
```

```
img_1 = plt.imread('image1.jpg')
img_2 = plt.imread('image2.jpg')
img_3 = plt.imread('image3.jpg')

fig, ax = plt.subplots(1, 3, figsize=(15, 30))
for a in ax:

  a.set_axis_off()
ax[0].imshow(img_1)
ax[1].imshow(img_2)
ax[2].imshow(img_3)
```

```
<matplotlib.image.AxesImage at 0x7f88cbc5f090>
```

```
res1 = panoramic_stitching(img_1, img_2)
cv2_imshow(res1)
```

```
(70, 3)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:31: VisibleDepre
```

```
res2 = panoramic_stitching(img_2, img_3)
cv2_imshow(res2)
```

```
(103, 3)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:31: VisibleDepre
```

```
cv2.imwrite('res1.jpg', res1)
cv2.imwrite('res2.jpg', res2)
```

```
True
```

```
res1 = cv2.imread('res1.jpg')
res2 = cv2.imread('res2.jpg')
```

```
res_final = panoramic_stitching(res1, res2)
cv2_imshow(res_final)
```

```
(68, 3)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:31: VisibleDepre
```