```
import numpy as np
import cv2
import scipy.io
import os
from numpy.linalg import norm
from matplotlib import pyplot as plt
from numpy.linalg import det
from numpy.linalg import inv
from scipy.linalg import rq
from numpy.linalg import svd
import matplotlib.pyplot as plt
import numpy as np
import math
import random
import sys
from scipy import ndimage, spatial
from tqdm.notebook import tqdm, trange

import torch
import torch.nn as nn
import torch.optim as optim
from torch.optim import lr_scheduler
from torch.autograd import Variable
import torchvision
from torchvision import datasets, models, transforms
from torch.utils.data import Dataset, DataLoader, ConcatDataset
from skimage import io, transform,data
from torchvision import transforms, utils
import numpy as np
import math
import glob
import matplotlib.pyplot as plt
import time
import os
import copy
import sklearn.svm
import cv2
from matplotlib import pyplot as plt
import numpy as np
from os.path import exists
import pandas as pd
import PIL
import random
from google.colab import drive
from sklearn.metrics.cluster import completeness_score
from sklearn.cluster import KMeans
from tqdm import tqdm, tqdm_notebook
from functools import partial
from torchsummary import summary
from torchvision.datasets import ImageFolder
```

```
from torch.utils.data.sampler import SubsetRandomSampler


from google.colab import drive

# This will prompt for authorization.
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mour
```

```
!pip install opencv-python==3.4.2.17
!pip install opencv-contrib-python==3.4.2.17
```

```
Requirement already satisfied: opencv-python==3.4.2.17 in /usr/local/lib/python3.7/dist-
Requirement already satisfied: numpy>=1.14.5 in /usr/local/lib/python3.7/dist-packages (
Requirement already satisfied: opencv-contrib-python==3.4.2.17 in /usr/local/lib/python3
Requirement already satisfied: numpy>=1.14.5 in /usr/local/lib/python3.7/dist-packages (
```

```
class Image:
    def __init__(self, img, position):

        self.img = img
        self.position = position

inlier_matchset = []
def features_matching(a,keypointlength,threshold):
  #threshold=0.2
  bestmatch=np.empty((keypointlength),dtype= np.int16)
  img1index=np.empty((keypointlength),dtype=np.int16)
  distance=np.empty((keypointlength))
  index=0
  for j in range(0,keypointlength):
    #For a descriptor fa in Ia, take the two closest descriptors fb1 and fb2 in Ib
    x=a[j]
    listx=x.tolist()
    x.sort()
    minval1=x[0]                                # min
    minval2=x[1]                                # 2nd min
    itemindex1 = listx.index(minval1)           #index of min val
    itemindex2 = listx.index(minval2)           #index of second min value
    ratio=minval1/minval2                       #Ratio Test

    if ratio<threshold:
      #Low distance ratio: fb1 can be a good match
      bestmatch[index]=itemindex1
      distance[index]=minval1
      img1index[index]=j
      index=index+1
  return  [cv2.DMatch(img1index[i],bestmatch[i].astype(int),distance[i]) for i in range(0,ind
```

```
def compute_Homography(im1_pts,im2_pts):
  """
  im1_pts and im2_pts are 2×n matrices with
  4 point correspondences from the two images
  """
  num_matches=len(im1_pts)
  num_rows = 2 * num_matches
  num_cols = 9
  A_matrix_shape = (num_rows,num_cols)
  A = np.zeros(A_matrix_shape)
  a_index = 0
  for i in range(0,num_matches):
    (a_x, a_y) = im1_pts[i]
    (b_x, b_y) = im2_pts[i]
    row1 = [a_x, a_y, 1, 0, 0, 0, -b_x*a_x, -b_x*a_y, -b_x] # First row
    row2 = [0, 0, 0, a_x, a_y, 1, -b_y*a_x, -b_y*a_y, -b_y] # Second row

    # place the rows in the matrix
    A[a_index] = row1
    A[a_index+1] = row2

    a_index += 2

  U, s, Vt = np.linalg.svd(A)

  #s is a 1-D array of singular values sorted in descending order
  #U, Vt are unitary matrices
  #Rows of Vt are the eigenvectors of A^TA.
  #Columns of U are the eigenvectors of AA^T.
  H = np.eye(3)
  H = Vt[-1].reshape(3,3) # take the last row of the Vt matrix
  return H


def displayplot(img,title):

  plt.figure(figsize=(15,15))
  plt.title(title)
  plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
  plt.show()


def get_inliers(f1, f2, matches, H, RANSACthresh):

  inlier_indices = []
  for i in range(len(matches)):
    queryInd = matches[i].queryIdx
    trainInd = matches[i].trainIdx

    #queryInd = matches[i][0]
```

```
        #queryInd = matches[i][0]
        #trainInd = matches[i][1]

        queryPoint = np.array([f1[queryInd].pt[0],  f1[queryInd].pt[1], 1]).T
        trans_query = H.dot(queryPoint)


        comp1 = [trans_query[0]/trans_query[2], trans_query[1]/trans_query[2]] # normalize with r
        comp2 = np.array(f2[trainInd].pt)[:2]


        if(np.linalg.norm(comp1-comp2) <= RANSACthresh): # check against threshold
          inlier_indices.append(i)
      return inlier_indices


    def RANSAC_alg(f1, f2, matches, nRANSAC, RANSACthresh):


        minMatches = 4
        nBest = 0
        best_inliers = []
        H_estimate = np.eye(3,3)
        global inlier_matchset
        inlier_matchset=[]
        for iteration in range(nRANSAC):

            #Choose a minimal set of feature matches.
            matchSample = random.sample(matches, minMatches)

            #Estimate the Homography implied by these matches
            im1_pts=np.empty((minMatches,2))
            im2_pts=np.empty((minMatches,2))
            for i in range(0,minMatches):
              m = matchSample[i]
              im1_pts[i] = f1[m.queryIdx].pt
              im2_pts[i] = f2[m.trainIdx].pt
              #im1_pts[i] = f1[m[0]].pt
              #im2_pts[i] = f2[m[1]].pt

            H_estimate=compute_Homography(im1_pts,im2_pts)


            # Calculate the inliers for the H
            inliers = get_inliers(f1, f2, matches, H_estimate, RANSACthresh)

            # if the number of inliers is higher than previous iterations, update the best estima
            if len(inliers) > nBest:
                nBest= len(inliers)
                best_inliers = inliers

        print("Number of best inliers",len(best_inliers))
```

```
        for i in range(len(best_inliers)):
          inlier_matchset.append(matches[best_inliers[i]])

        # compute a homography given this set of matches
        im1_pts=np.empty((len(best_inliers),2))
        im2_pts=np.empty((len(best_inliers),2))
        for i in range(0,len(best_inliers)):
          m = inlier_matchset[i]
          im1_pts[i] = f1[m.queryIdx].pt
          im2_pts[i] = f2[m.trainIdx].pt
          #im1_pts[i] = f1[m[0]].pt
          #im2_pts[i] = f2[m[1]].pt

        M=compute_Homography(im1_pts,im2_pts)
        return M, best_inliers


    files_all=[]
    for file in os.listdir("/content/drive/MyDrive/RGB-img/img"):
        if file.endswith(".JPG"):
          files_all.append(file)


    files_all.sort()
    folder_path = '/content/drive/MyDrive/RGB-img/img/'

    centre_file = folder_path + files_all[15]
    left_files_path_rev = []
    right_files_path = []

    for file in files_all[:51]:
      left_files_path_rev.append(folder_path + file)

    left_files_path = left_files_path_rev[::-1]

    for file in files_all[50:100]:
      right_files_path.append(folder_path + file)


    from PIL.ExifTags import TAGS
    from PIL.ExifTags import GPSTAGS
    from PIL import Image
    def get_exif(filename):
        image = Image.open(filename)
        image.verify()
        return image._getexif()

    def get_labeled_exif(exif):
        labeled = {}
        for (key, val) in exif.items():
            labeled[TAGS.get(key)] = val
```

```
        return labeled


    def get_geotagging(exif):
        if not exif:
            raise ValueError("No EXIF metadata found")

        geotagging = {}
        for (idx, tag) in TAGS.items():
            if tag == 'GPSInfo':
                if idx not in exif:
                    raise ValueError("No EXIF geotagging found")

                for (key, val) in GPSTAGS.items():
                    if key in exif[idx]:
                        geotagging[val] = exif[idx][key]
        return geotagging

    def get_decimal_from_dms(dms, ref):

        degrees = dms[0][0] / dms[0][1]
        minutes = dms[1][0] / dms[1][1] / 60.0
        seconds = dms[2][0] / dms[2][1] / 3600.0

        if ref in ['S', 'W']:
            degrees = -degrees
            minutes = -minutes
            seconds = -seconds

        return round(degrees + minutes + seconds, 5)

    def get_coordinates(geotags):
        lat = get_decimal_from_dms(geotags['GPSLatitude'], geotags['GPSLatitudeRef'])

        lon = get_decimal_from_dms(geotags['GPSLongitude'], geotags['GPSLongitudeRef'])

        return (lat,lon)


    gridsize = 8
    clahe = cv2.createCLAHE(clipLimit=2.0,tileGridSize=(gridsize,gridsize))

    images_left_bgr = []
    images_right_bgr = []

    images_left = []
    images_right = []

    for file in tqdm(left_files_path):
      left_image_sat= cv2.imread(file)
      lab = cv2.cvtColor(left_image_sat, cv2.COLOR_BGR2LAB)
      lab[...,0] = clahe.apply(lab[...,0])
```

```
    left_image_sat = cv2.cvtColor(lab, cv2.COLOR_LAB2BGR)
    left_img = cv2.resize(left_image_sat,None,fx=0.35, fy=0.35, interpolation = cv2.INTER_CUBIC
    images_left.append(cv2.cvtColor(left_img, cv2.COLOR_BGR2GRAY).astype('float32')/255.)
    images_left_bgr.append(left_img)


  for file in tqdm(right_files_path):
    right_image_sat= cv2.imread(file)
    lab = cv2.cvtColor(right_image_sat, cv2.COLOR_BGR2LAB)
    lab[...,0] = clahe.apply(lab[...,0])
    right_image_sat = cv2.cvtColor(lab, cv2.COLOR_LAB2BGR)
    right_img = cv2.resize(right_image_sat,None,fx=0.35,fy=0.35, interpolation = cv2.INTER_CUBI
    images_right.append(cv2.cvtColor(right_img, cv2.COLOR_BGR2GRAY).astype('float32')/255.)
    images_right_bgr.append(right_img)
```

```
100%|██████████| 51/51 [00:49<00:00,  1.04it/s]
100%|██████████| 50/50 [00:47<00:00,  1.04it/s]
```

```
  images_left_bgr_no_enhance = []
  images_right_bgr_no_enhance = []


  for file in tqdm(left_files_path):
    left_image_sat= cv2.imread(file)
    left_img = cv2.resize(left_image_sat,None,fx=0.35, fy=0.35, interpolation = cv2.INTER_CUBIC
    images_left_bgr_no_enhance.append(left_img)


  for file in tqdm(right_files_path):
    right_image_sat= cv2.imread(file)
    right_img = cv2.resize(right_image_sat,None,fx=0.35,fy=0.35, interpolation = cv2.INTER_CUBI
    images_right_bgr_no_enhance.append(right_img)
```

```
100%|██████████| 51/51 [00:17<00:00,  2.88it/s]
100%|██████████| 50/50 [00:19<00:00,  2.57it/s]
```

```
  daisy = cv2.xfeatures2d.DAISY_create()
  sift = cv2.xfeatures2d.SIFT_create()

  keypoints_all_left_daisy = []
  descriptors_all_left_daisy = []
  points_all_left_daisy=[]

  keypoints_all_right_daisy = []
  descriptors_all_right_daisy = []
  points_all_right_daisy=[]

  for imgs in tqdm(images_left_bgr_no_enhance):
    kpt = sift.detect(imgs,None)
    kpt,descrip =  daisy.compute(imgs, kpt)
    keypoints_all_left_daisy.append(kpt)
```

```
    descriptors_all_left_daisy.append(descrip)
    points_all_left_daisy.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

  for imgs in tqdm(images_right_bgr_no_enhance):
    kpt = sift.detect(imgs,None)
    kpt,descrip =  daisy.compute(imgs, kpt)
    keypoints_all_right_daisy.append(kpt)
    descriptors_all_right_daisy.append(descrip)
    points_all_right_daisy.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 51/51 [01:02<00:00,  1.23s/it]
100%|██████████| 50/50 [01:00<00:00,  1.22s/it]
```

```
  #num_kps_sift = []
  #num_kps_brisk = []
  #num_kps_agast = []
  #num_kps_kaze = []
  #num_kps_akaze = []
  #num_kps_orb = []
  #num_kps_mser = []
  num_kps_daisy = []
  #num_kps_surfsift = []
  #num_kps_fast = []
  #num_kps_freak = []
  #num_kps_gftt = []
  #num_kps_star = []

  #for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
  #  num_kps_sift.append(len(j))

  #for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
    #num_kps_brisk.append(len(j))

  #for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
    #num_kps_agast.append(len(j))

  #for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
  #  num_kps_kaze.append(len(j))

  #for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
    #num_kps_akaze.append(len(j))

  #for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
    #num_kps_orb.append(len(j))

  #for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
   # num_kps_mser.append(len(j))

  for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
    num_kps_daisy.append(len(j))
```

```
#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
  #num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  #num_kps_freak.append(len(j))

#for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
  #num_kps_gftt.append(len(j))

#for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  #num_kps_star.append(len(j))
```

```
100%|██████████| 101/101 [00:00<00:00, 42277.91it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])
```

```
matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

print("\nNumber of matches",len(matches_lf1_lf))

matches_4 = []
ratio = ratio
# loop over the raw matches
for m in matches_lf1_lf:
  # ensure the distance is within a certain ratio of each
  # other (i.e. Lowe’s ratio test)
  if len(m) == 2 and m[0].distance < m[1].distance * ratio:
      #matches_1.append((m[0].trainIdx, m[0].queryIdx))
      matches_4.append(m[0])

print("Number of matches After Lowe's Ratio",len(matches_4))

matches_idx = np.array([m.queryIdx for m in matches_4])
imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
matches_idx = np.array([m.trainIdx for m in matches_4])
imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
'''
# Estimate homography 1
#Compute H1
# Estimate homography 1
#Compute H1
imm1_pts=np.empty((len(matches_4),2))
imm2_pts=np.empty((len(matches_4),2))
for i in range(0,len(matches_4)):
  m = matches_4[i]
  (a_x, a_y) = keypts[0][m.queryIdx].pt
  (b_x, b_y) = keypts[1][m.trainIdx].pt
  imm1_pts[i]=(a_x, a_y)
  imm2_pts[i]=(b_x, b_y)
H=compute_Homography(imm1_pts,imm2_pts)
#Robustly estimate Homography 1 using RANSAC
Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
'''



Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
print("Number of Robust matches",len(inlier_matchset))
print("\n")
'''
if len(inlier_matchset)<50:
  matches_4 = []
  ratio = 0.67
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
```

```
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])
    print("Number of matches After Lowe's Ratio New",len(matches_4))

    matches_idx = np.array([m.queryIdx for m in matches_4])
    imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
    matches_idx = np.array([m.trainIdx for m in matches_4])
    imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
    Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches New",len(inlier_matchset))
    print("\n")
    '''
  #H=compute_Homography(imm1_pts,imm2_pts)
  #Robustly estimate Homography 1 using RANSAC
  #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

  #global inlier_matchset

  if disp==True:
    dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
    displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

  return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
s_left))):
```

```
t_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_daisy[j:j+2][::-1],points_all_left_d

tches)
nd(gd_matches)

s_right))):



t_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_daisy[j:j+2][::-1],points_all_righ

)
_matches)
```

```
Number of matches 18754
Number of matches After Lowe's Ratio 4311
Number of Robust matches 1713


 80%|████████  | 40/50 [02:23<00:35,  3.55s/it]
Number of matches 20522
Number of matches After Lowe's Ratio 1983
Number of Robust matches 828


 82%|████████▏  | 41/50 [02:27<00:32,  3.61s/it]
Number of matches 20368
Number of matches After Lowe's Ratio 2026
Number of Robust matches 898


 84%|████████▍  | 42/50 [02:30<00:28,  3.61s/it]
Number of matches 19692
Number of matches After Lowe's Ratio 2928
Number of Robust matches 1468


 86%|████████▌ | 43/50 [02:34<00:24,  3.57s/it]
Number of matches 17996
Number of matches After Lowe's Ratio 2146
Number of Robust matches 1205


 88%|████████▊ | 44/50 [02:37<00:20,  3.43s/it]
Number of matches 17038
Number of matches After Lowe's Ratio 1656
Number of Robust matches 1114


 90%|█████████ | 45/50 [02:40<00:16,  3.32s/it]
Number of matches 17238
Number of matches After Lowe's Ratio 2336
Number of Robust matches 1646
```

```
 92%|█████████▏ | 46/50 [02:43<00:13,  3.26s/it]
Number of matches 16004
Number of matches After Lowe's Ratio 2172
Number of Robust matches 1349


 94%|█████████▍ | 47/50 [02:46<00:09,  3.09s/it]
Number of matches 15671
Number of matches After Lowe's Ratio 4312
Number of Robust matches 2370


 96%|█████████▌| 48/50 [02:49<00:05,  2.95s/it]
Number of matches 16163
Number of matches After Lowe's Ratio 2002
Number of Robust matches 975
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
```

```
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
```

```
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result
```

```
      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en


 Step1:Done
 Step2:Done


warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_daisy,xmax,xmin,yma



warp_imgs_all_daisy = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H_ri



fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_daisy, cv2.COLOR_BGR2RGB))
```

```
ax.imshow(cv2.cvtColor(warp_imgs_all_daisy , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-DAISY')
```

```
star = cv2.xfeatures2d.StarDetector_create()
brief = cv2.xfeatures2d.BriefDescriptorExtractor_create()

keypoints_all_left_star = []
descriptors_all_left_brief = []
points_all_left_star=[]

keypoints_all_right_star = []
descriptors_all_right_brief = []
points_all_right_star=[]

for imgs in tqdm(images_left_bgr):
  kpt = star.detect(imgs,None)
  kpt,descrip =  brief.compute(imgs, kpt)
  keypoints_all_left_star.append(kpt)
  descriptors_all_left_brief.append(descrip)
  points_all_left_star.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr):
  kpt = star.detect(imgs,None)
  kpt,descrip =  brief.compute(imgs, kpt)
  keypoints_all_right_star.append(kpt)
  descriptors_all_right_brief.append(descrip)
  points_all_right_star.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 51/51 [00:08<00:00,  6.21it/s]
100%|██████████| 50/50 [00:07<00:00,  6.43it/s]
```

```
#num_kps_sift = []
#num_kps_brisk = []
#num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
#num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
#num_kps_fast = []
#num_kps_freak = []
#num_kps_gftt = []
num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))
```

```
#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

#for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
  #num_kps_agast.append(len(j))

#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

#for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
 # num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
  #num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  #num_kps_freak.append(len(j))

#for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
  #num_kps_gftt.append(len(j))

for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  num_kps_star.append(len(j))


def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)
```

```
    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])

  print("Number of matches After Lowe's Ratio",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
  matches_idx = np.array([m.trainIdx for m in matches_4])
  imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
  '''
  # Estimate homography 1
  #Compute H1
  # Estimate homography 1
  #Compute H1
  imm1_pts=np.empty((len(matches_4),2))
  imm2_pts=np.empty((len(matches_4),2))
  for i in range(0,len(matches_4)):
    m = matches_4[i]
    (a_x, a_y) = keypts[0][m.queryIdx].pt
    (b_x, b_y) = keypts[1][m.trainIdx].pt
    imm1_pts[i]=(a_x, a_y)
```

```
      imm2_pts[i]=(b_x, b_y)
    H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
    '''



    Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches",len(inlier_matchset))
    print("\n")
    '''
    if len(inlier_matchset)<50:
      matches_4 = []
      ratio = 0.67
      # loop over the raw matches
      for m in matches_lf1_lf:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe's ratio test)
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])
      print("Number of matches After Lowe's Ratio New",len(matches_4))

      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
H_left_brief = []
H_right_brief = []

num_matches_brief = []
num_good_matches_brief = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_star[j
  H_left_brief.append(H_a)
  num_matches_brief.append(matches)
  num_good_matches_brief.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_star
  H_right_brief.append(H_a)
  num_matches_brief.append(matches)
  num_good_matches_brief.append(gd_matches)
```

```
  4%|▌         | 2/51 [00:00<00:10,  4.88it/s]
Number of matches 5057
Number of matches After Lowe's Ratio 26
Number of Robust matches 9



Number of matches 8104
Number of matches After Lowe's Ratio 16
Number of Robust matches 8


  8%|▊         | 4/51 [00:00<00:08,  5.36it/s]
Number of matches 5316
Number of matches After Lowe's Ratio 6
Number of Robust matches 5



Number of matches 6815
Number of matches After Lowe's Ratio 45
Number of Robust matches 30


  8%|▊         | 4/51 [00:00<00:10,  4.30it/s]
Number of matches 6920
Number of matches After Lowe's Ratio 2
Number of Robust matches 0
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
```

```
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')
```

```
        return warp_imgs_left

    def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

        warp_imgs_right = []

        for j,H in enumerate(H_right):
          if j==0:
            H_trans = Ht@H
          else:
            H_trans = H_trans@H
          result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

          warp_imgs_right.append(result)

        print('Step32:Done')

        return warp_imgs_right

    def final_steps_union(warp_imgs_left,warp_imgs_right):
        #Union

        warp_images_all = warp_imgs_left + warp_imgs_right

        warp_img_init = warp_images_all[0]



        #warp_final_all=[]

        for j,warp_img in enumerate(warp_images_all):
          if j==len(warp_images_all)-1:
            break
          black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

          warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

          #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
          #warp_img_init = warp_final
          #warp_final_all.append(warp_final)

        print('Step4:Done')


        return warp_img_init


    def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):
```

```
    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en


 Step1:Done
 Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_brief,xmax,xmin,yma
```

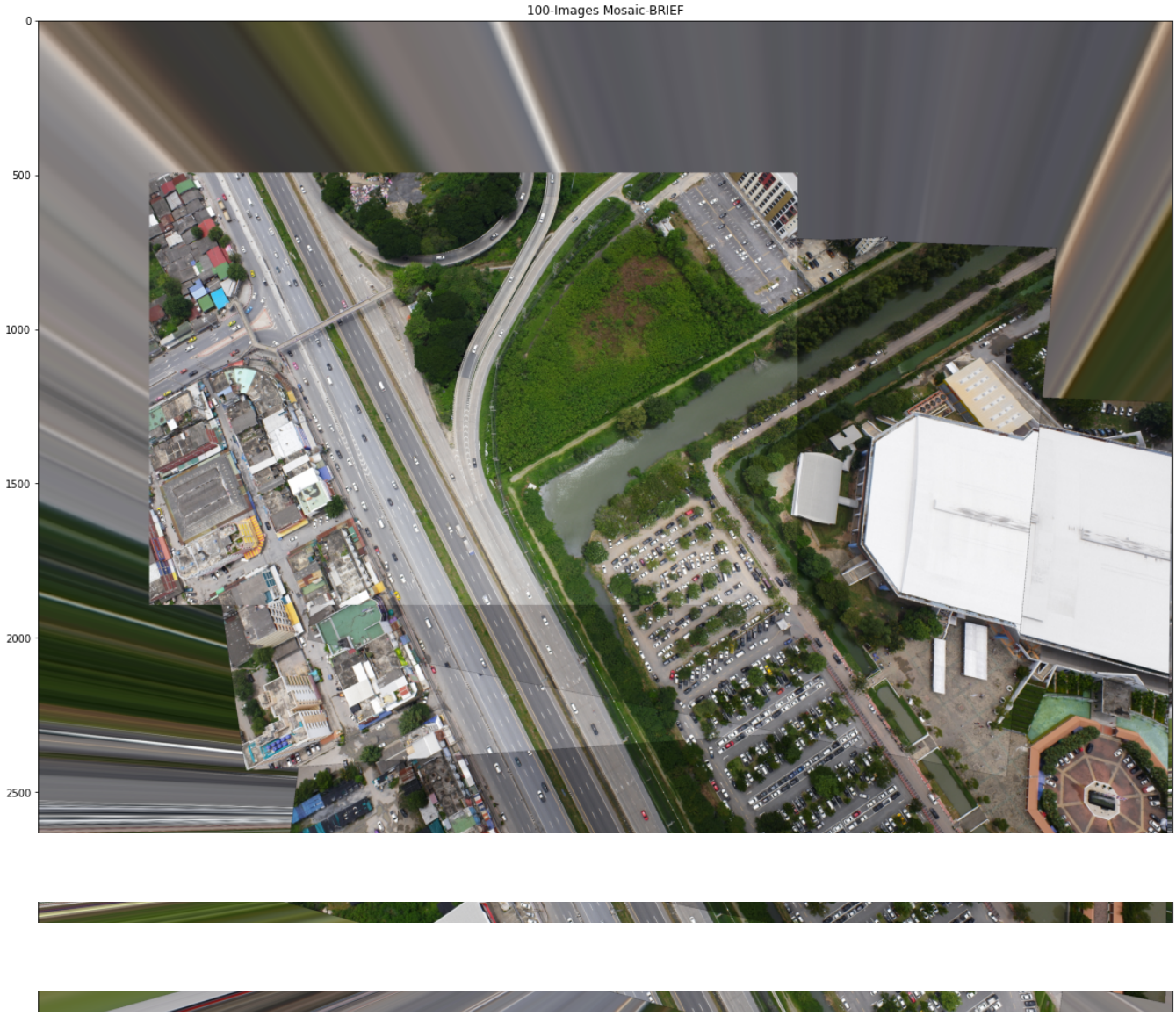
```
     Step31:Done
```

```
warp_imgs_all_brief = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H_ri
```

```
     Step32:Done
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_brief , cv2.COLOR_BGR2RGB))
ax.set_title('100-Images Mosaic-BRIEF')
```

```
Text(0.5, 1.0, '100-Images Mosaic-BRIEF')
```




```
class RootSIFT:
  def __init__(self):
    # initialize the SIFT feature extractor
    #self.extractor = cv2.DescriptorExtractor_create("SIFT")
    self.sift = cv2.xfeatures2d.SIFT_create()

  def compute(self, image, kps, eps=1e-7):
    # compute SIFT descriptors
    (kps, descs) = self.sift.compute(image, kps)

    # if there are no keypoints or descriptors, return an empty tuple
    if len(kps) == 0:
      return ([], None)

    # apply the Hellinger kernel by first L1-normalizing, taking the
    # square-root, and then L2-normalizing
    descs /= (np.linalg.norm(descs, axis=0, ord=2) + eps)
    descs /= (descs.sum(axis=0) + eps)
    descs = np.sqrt(descs)
```

```
        #descs /= (np.linalg.norm(descs, axis=0, ord=2) + eps)

        # return a tuple of the keypoints and descriptors
        return (kps, descs)


    sift = cv2.xfeatures2d.SIFT_create()
    rootsift = RootSIFT()
    keypoints_all_left_rootsift = []
    descriptors_all_left_rootsift = []
    points_all_left_rootsift=[]

    keypoints_all_right_rootsift = []
    descriptors_all_right_rootsift = []
    points_all_right_rootsift=[]

    for imgs in tqdm(images_left_bgr):
      kpt = sift.detect(imgs,None)
      kpt,descrip =  rootsift.compute(imgs, kpt)
      keypoints_all_left_rootsift.append(kpt)
      descriptors_all_left_rootsift.append(descrip)
      points_all_left_rootsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

    for imgs in tqdm(images_right_bgr):
      kpt = sift.detect(imgs,None)
      kpt,descrip =  rootsift.compute(imgs, kpt)
      keypoints_all_right_rootsift.append(kpt)
      descriptors_all_right_rootsift.append(descrip)
      points_all_right_rootsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

       100%|██████████| 61/61 [03:18<00:00,  3.25s/it]
       100%|██████████| 60/60 [03:14<00:00,  3.24s/it]




    sift = cv2.xfeatures2d.SIFT_create()
    keypoints_all_left_sift = []
    descriptors_all_left_sift = []
    points_all_left_sift=[]

    keypoints_all_right_sift = []
    descriptors_all_right_sift = []
    points_all_right_sift=[]

    for imgs in tqdm(images_left_bgr):
      kpt = sift.detect(imgs,None)
      kpt,descrip =  sift.compute(imgs, kpt)
      keypoints_all_left_sift.append(kpt)
      descriptors_all_left_sift.append(descrip)
      points_all_left_sift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
for imgs in tqdm(images_right_bgr):
  kpt = sift.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_sift.append(kpt)
  descriptors_all_right_sift.append(descrip)
  points_all_right_sift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 61/61 [03:22<00:00,  3.32s/it]
100%|██████████| 61/61 [03:09<00:00,  3.11s/it]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
```

```
ratio = ratio
# loop over the raw matches
for m in matches_lf1_lf:
  # ensure the distance is within a certain ratio of each
  # other (i.e. Lowe’s ratio test)
  if len(m) == 2 and m[0].distance < m[1].distance * ratio:
      #matches_1.append((m[0].trainIdx, m[0].queryIdx))
      matches_4.append(m[0])

print("Number of matches After Lowe's Ratio",len(matches_4))

matches_idx = np.array([m.queryIdx for m in matches_4])
imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
matches_idx = np.array([m.trainIdx for m in matches_4])
imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
'''
# Estimate homography 1
#Compute H1
# Estimate homography 1
#Compute H1
imm1_pts=np.empty((len(matches_4),2))
imm2_pts=np.empty((len(matches_4),2))
for i in range(0,len(matches_4)):
  m = matches_4[i]
  (a_x, a_y) = keypts[0][m.queryIdx].pt
  (b_x, b_y) = keypts[1][m.trainIdx].pt
  imm1_pts[i]=(a_x, a_y)
  imm2_pts[i]=(b_x, b_y)
H=compute_Homography(imm1_pts,imm2_pts)
#Robustly estimate Homography 1 using RANSAC
Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
'''



Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
print("Number of Robust matches",len(inlier_matchset))
print("\n")
'''
if len(inlier_matchset)<50:
  matches_4 = []
  ratio = 0.67
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])
  print("Number of matches After Lowe's Ratio New",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
```

```
      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0061.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0060.JPG', '/content/drive/MyDrive
```

```
H_left_rootsift = []
H_right_rootsift = []

num_matches_rootsift = []
num_good_matches_rootsift = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_rootsi
  H_left_rootsift.append(H_a)
  num_matches_rootsift.append(matches)
  num_good_matches_rootsift.append(gd_matches)
```

```
for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_root
  H_right_rootsift.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/61 [00:06<06:35,  6.59s/it]
Number of matches 28871
Number of matches After Lowe's Ratio 2381
Number of Robust matches 1347


  3%|▎          | 2/61 [00:13<06:28,  6.59s/it]
Number of matches 35330
Number of matches After Lowe's Ratio 1675
Number of Robust matches 879


  5%|▍          | 3/61 [00:20<06:43,  6.96s/it]
Number of matches 32332
Number of matches After Lowe's Ratio 626
Number of Robust matches 245


  7%|▋          | 4/61 [00:28<06:39,  7.01s/it]
Number of matches 32125
Number of matches After Lowe's Ratio 4695
Number of Robust matches 2562


  8%|▊          | 5/61 [00:35<06:36,  7.08s/it]
Number of matches 32463
Number of matches After Lowe's Ratio 5257
Number of Robust matches 3471


 10%|▉          | 6/61 [00:44<07:06,  7.76s/it]
Number of matches 32266
Number of matches After Lowe's Ratio 4943
Number of Robust matches 2575


 11%|█          | 7/61 [00:54<07:33,  8.40s/it]
Number of matches 32877
Number of matches After Lowe's Ratio 5372
Number of Robust matches 3219


 13%|█▏         | 8/61 [01:02<07:10,  8.12s/it]
Number of matches 27613
Number of matches After Lowe's Ratio 3080
Number of Robust matches 2047
```

```
 15%|█▌        | 9/61 [01:07<06:27,  7.45s/it]
Number of matches 31966
Number of matches After Lowe's Ratio 4270
Number of Robust matches 2660


 16%|█▋        | 10/61 [01:14<06:05,  7.17s/it]
Number of matches 23666
Number of matches After Lowe's Ratio 1857
Number of Robust matches 1229
```

```
H_left_sift = []
H_right_sift = []

num_matches_sift = []
num_good_matches_sift = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_sift[j
  H_left_sift.append(H_a)
  num_matches_sift.append(matches)
  num_good_matches_sift.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_sift
  H_right_sift.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▏         | 1/61 [00:06<06:32,  6.55s/it]
Number of matches 28871
Number of matches After Lowe's Ratio 571
Number of Robust matches 480


  3%|▎         | 2/61 [00:13<06:26,  6.55s/it]
Number of matches 35330
Number of matches After Lowe's Ratio 352
```

```
Number of Robust matches 281


  5%|▌         | 3/61 [00:20<06:39,  6.88s/it]
Number of matches 32332
Number of matches After Lowe's Ratio 74
Number of Robust matches 54


  7%|▋         | 4/61 [00:27<06:33,  6.91s/it]
Number of matches 32125
Number of matches After Lowe's Ratio 1498
Number of Robust matches 975


  8%|▊         | 5/61 [00:34<06:32,  7.01s/it]
Number of matches 32463
Number of matches After Lowe's Ratio 1694
Number of Robust matches 898


 10%|▉         | 6/61 [00:41<06:25,  7.00s/it]
Number of matches 32266
Number of matches After Lowe's Ratio 1656
Number of Robust matches 1037


 11%|█         | 7/61 [00:49<06:19,  7.04s/it]
Number of matches 32877
Number of matches After Lowe's Ratio 1815
Number of Robust matches 1011


 13%|█▏        | 8/61 [00:55<06:09,  6.97s/it]
Number of matches 27613
Number of matches After Lowe's Ratio 759
Number of Robust matches 517


 15%|█▎        | 9/61 [01:01<05:39,  6.53s/it]
Number of matches 31966
Number of matches After Lowe's Ratio 1288
Number of Robust matches 820


 16%|█▍        | 10/61 [01:08<05:37,  6.62s/it]
Number of matches 23666
Number of matches After Lowe's Ratio 502
Number of Robust matches 428
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts left = []
```

```
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht
```

```
def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
```

```
          break
        black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

        warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

        #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
        #warp_img_init = warp_final
        #warp_final_all.append(warp_final)

      print('Step4:Done')


      return warp_img_init


  def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



      for j,H in enumerate(H_left):
        if j==0:
          H_trans = Ht@H
        else:
          H_trans = H_trans@H
        input_img = images_left[j+1]
        result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

        cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
        warp_img_init_curr = result

        if j==0:
          result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
          warp_img_init_prev = result
          continue

        black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

        warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

      print('Step31:Done')

      return warp_img_init_prev

  def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

      for j,H in enumerate(H_right):
        if j==0:
          H_trans = Ht@H
        else:
          H_trans = H_trans@H
        input_img = images_right[j+1]
        result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')
```

```
        cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
        warp_img_init_curr = result

        black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

        warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

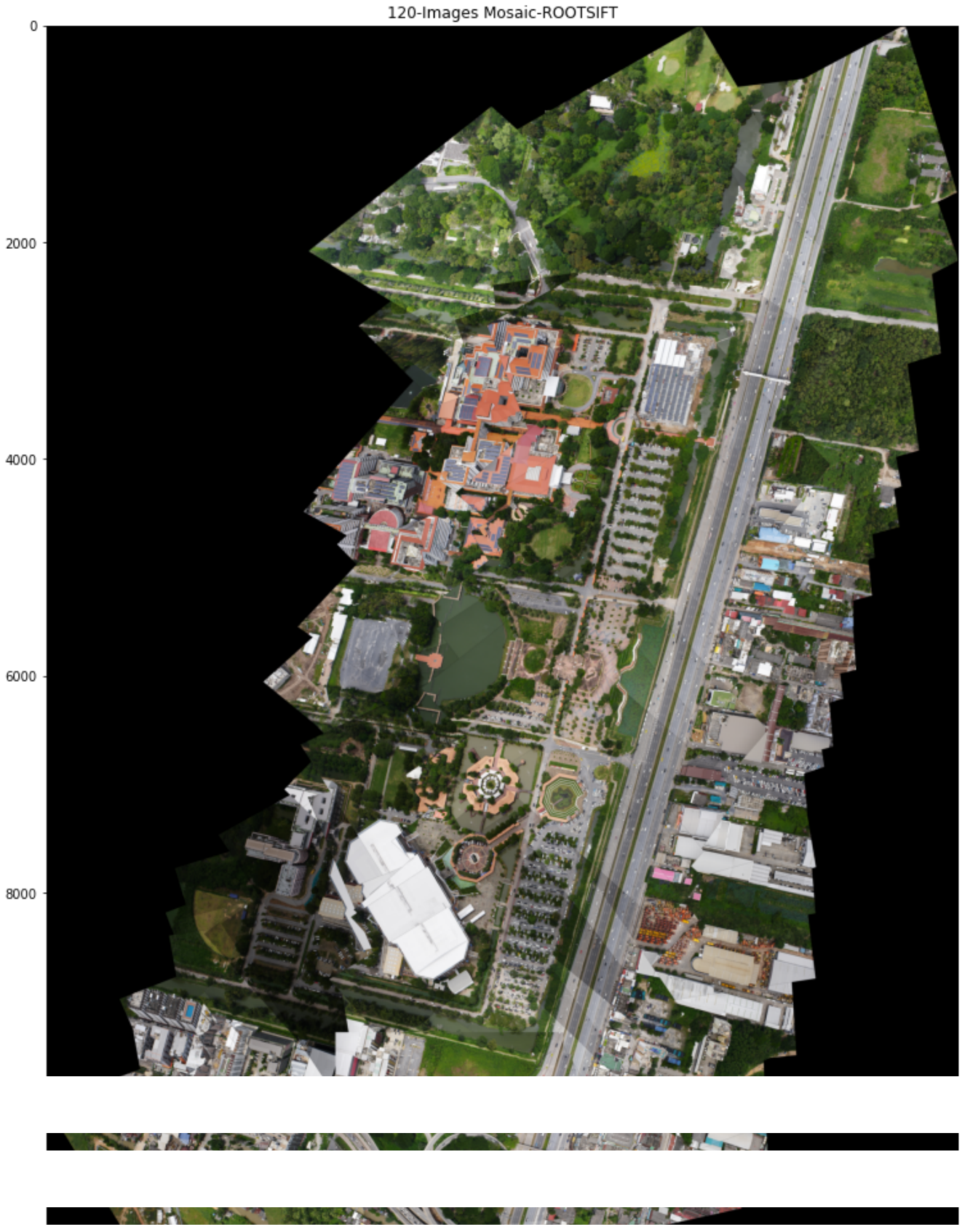
```
Step1:Done
Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_rootsift,xmax,xmin,


warp_imgs_all_rootsift = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H
```

```
Step32:Done
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_rootsift , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-ROOTSIFT')
```

```
Text(0.5, 1.0, '120-Images Mosaic-ROOTSIFT')
```




```
xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

```
Step1:Done
Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_sift,xmax,xmin,ymax
```

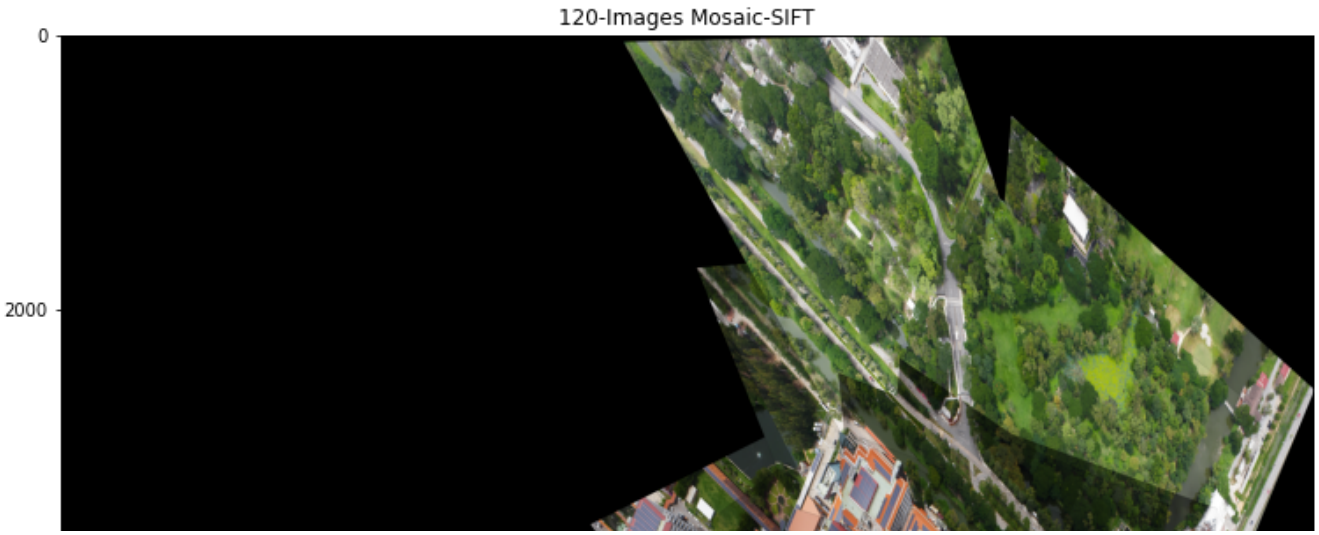
```
Step31:Done
```

```
warp_imgs_all_sift = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H_rig
```

```
Step32:Done
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_sift , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-SIFT')
```

```
Text(0.5, 1.0, '120-Images Mosaic-SIFT')
```




```
akaze = cv2.AKAZE_create()


keypoints_all_left_akaze = []
descriptors_all_left_akaze = []
points_all_left_akaze=[]

keypoints_all_right_akaze = []
descriptors_all_right_akaze = []
points_all_right_akaze=[]

for imgs in tqdm(images_left_bgr):
  kpt = akaze.detect(imgs,None)
  kpt,descrip =  akaze.compute(imgs, kpt)
  keypoints_all_left_akaze.append(kpt)
  descriptors_all_left_akaze.append(descrip)
  points_all_left_akaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr):
  kpt = akaze.detect(imgs,None)
  kpt,descrip =  akaze.compute(imgs, kpt)
  keypoints_all_right_akaze.append(kpt)
  descriptors_all_right_akaze.append(descrip)
  points_all_right_akaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 61/61 [01:29<00:00,  1.47s/it]
100%|██████████| 61/61 [01:28<00:00,  1.45s/it]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
```

```
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
        inliers = inliers.flatten()
        return H, inliers


    def compute_homography_fast_other(matched_pts1, matched_pts2):
        #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
        #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

        # Estimate the homography between the matches using RANSAC
        H, inliers = cv2.findHomography(matched_pts1,
                                        matched_pts2,
                                        0)
        inliers = inliers.flatten()
        return H, inliers


    def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
      FLANN_INDEX_KDTREE = 2
      index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
      search_params = dict(checks=50)
      flann = cv2.FlannBasedMatcher(index_params, search_params)
      #flann = cv2.BFMatcher()

      lff1 = np.float32(descripts[0])
      lff = np.float32(descripts[1])


      matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

      print("\nNumber of matches",len(matches_lf1_lf))

      matches_4 = []
      ratio = ratio
      # loop over the raw matches
      for m in matches_lf1_lf:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe’s ratio test)
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])

      print("Number of matches After Lowe's Ratio",len(matches_4))

      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      '''
      # Estimate homography 1
      #Compute H1
      # Estimate homography 1
      #Compute H1
```

```
    #Compute H1
    imm1_pts=np.empty((len(matches_4),2))
    imm2_pts=np.empty((len(matches_4),2))
    for i in range(0,len(matches_4)):
      m = matches_4[i]
      (a_x, a_y) = keypts[0][m.queryIdx].pt
      (b_x, b_y) = keypts[1][m.trainIdx].pt
      imm1_pts[i]=(a_x, a_y)
      imm2_pts[i]=(b_x, b_y)
    H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
    '''



    Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches",len(inlier_matchset))
    print("\n")
    '''
    if len(inlier_matchset)<50:
      matches_4 = []
      ratio = 0.67
      # loop over the raw matches
      for m in matches_lf1_lf:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe’s ratio test)
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])
      print("Number of matches After Lowe's Ratio New",len(matches_4))

      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)
```

```
from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)
```

```
print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0064.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0063.JPG', '/content/drive/MyDrive
```

```
H_left_akaze = []
H_right_akaze = []

num_matches_akaze = []
num_good_matches_akaze = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_akaze[
  H_left_akaze.append(H_a)
  num_matches_akaze.append(matches)
  num_good_matches_akaze.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_akaz
  H_right_akaze.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/61 [00:01<01:37,  1.63s/it]
Number of matches 20771
Number of matches After Lowe's Ratio 2771
Number of Robust matches 2138


  3%|▎          | 2/61 [00:03<01:38,  1.67s/it]
Number of matches 18233
Number of matches After Lowe's Ratio 2533
Number of Robust matches 1689
```

```
  5%|▌          | 3/61 [00:04<01:32,  1.60s/it]
Number of matches 16819
Number of matches After Lowe's Ratio 1416
Number of Robust matches 834


  7%|▋          | 4/61 [00:06<01:27,  1.53s/it]
Number of matches 16167
Number of matches After Lowe's Ratio 992
Number of Robust matches 437


  8%|▊          | 5/61 [00:07<01:23,  1.49s/it]
Number of matches 21720
Number of matches After Lowe's Ratio 912
Number of Robust matches 264


 10%|▉          | 6/61 [00:09<01:27,  1.58s/it]
Number of matches 18547
Number of matches After Lowe's Ratio 453
Number of Robust matches 32


 11%|█          | 7/61 [00:10<01:24,  1.57s/it]
Number of matches 18110
Number of matches After Lowe's Ratio 2194
Number of Robust matches 1278


 13%|█▏         | 8/61 [00:12<01:22,  1.55s/it]
Number of matches 18754
Number of matches After Lowe's Ratio 2316
Number of Robust matches 1354


 15%|█▎         | 9/61 [00:14<01:20,  1.56s/it]
Number of matches 19049
Number of matches After Lowe's Ratio 2346
Number of Robust matches 1152


 16%|█▍         | 10/61 [00:15<01:22,  1.62s/it]
Number of matches 20428
Number of matches After Lowe's Ratio 2484
Number of Robust matches 1632
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []
```

```
    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):
```

```
def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
```

```
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')
```

```
        cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
        warp_img_init_curr = result

        black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

        warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

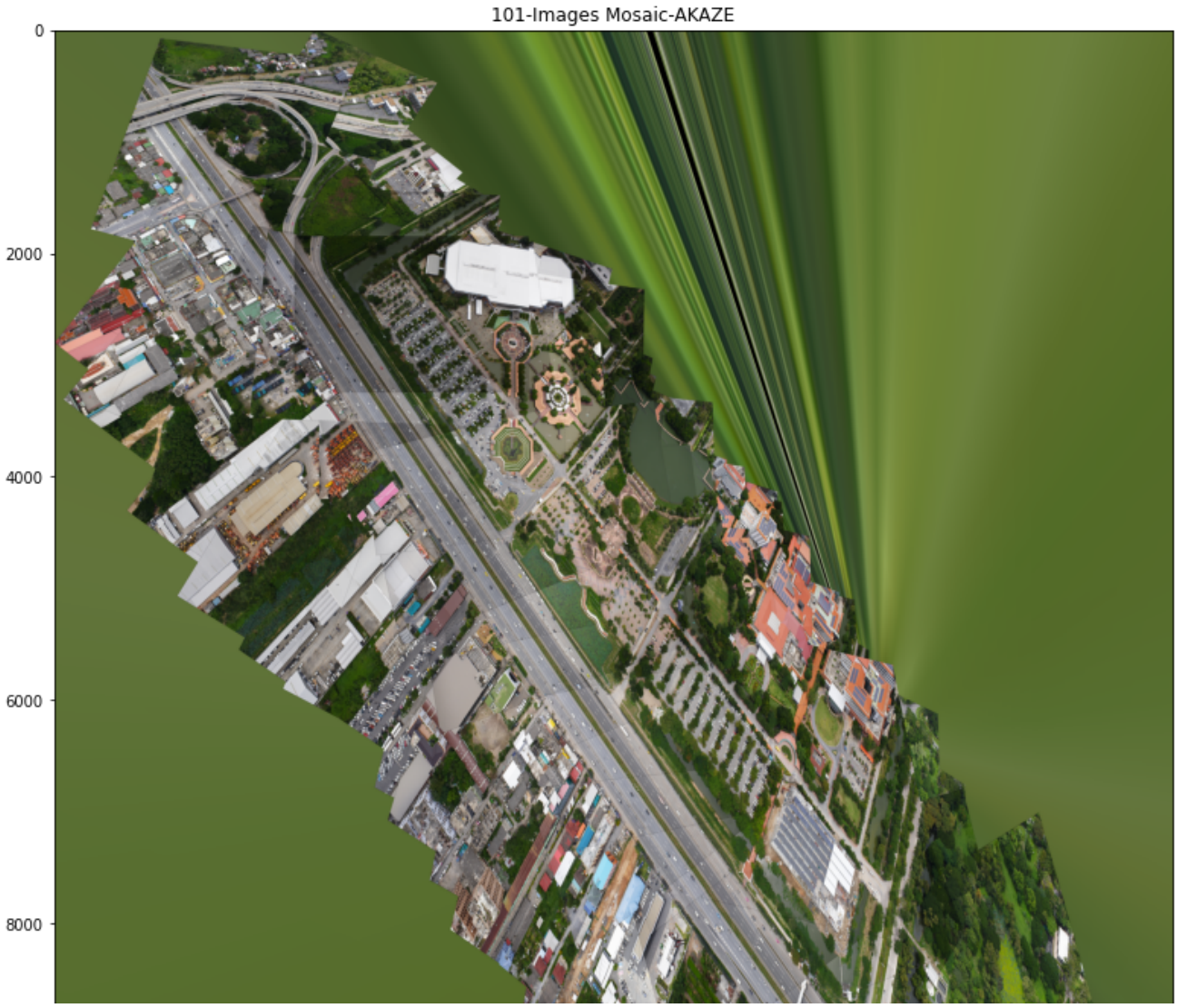
```
Step1:Done
Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_akaze,xmax,xmin,yma


warp_imgs_all_akaze = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H_ri
```

```
Step32:Done
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_akaze , cv2.COLOR_BGR2RGB))
ax.set_title('101-Images Mosaic-AKAZE')
```

```
Text(0.5, 1.0, '101-Images Mosaic-AKAZE')
```




```
Threshl=60;
Octaves=8;
#PatternScales=1.0f;
brisk = cv2.BRISK_create(Threshl,Octaves)


keypoints_all_left_brisk = []
descriptors_all_left_brisk = []
points_all_left_brisk=[]

keypoints_all_right_brisk = []
descriptors_all_right_brisk = []
points_all_right_brisk=[]

for imgs in tqdm(images_left_bgr):
  kpt = brisk.detect(imgs,None)
  kpt,descrip =  brisk.compute(imgs, kpt)
  keypoints_all_left_brisk.append(kpt)
  descriptors_all_left_brisk.append(descrip)
  points_all_left_brisk.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
for imgs in tqdm(images_right_bgr):
  kpt = brisk.detect(imgs,None)
  kpt,descrip =  brisk.compute(imgs, kpt)
  keypoints_all_right_brisk.append(kpt)
  descriptors_all_right_brisk.append(descrip)
  points_all_right_brisk.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
   100%|██████████| 61/61 [01:04<00:00,  1.05s/it]
   100%|██████████| 61/61 [00:55<00:00,  1.10it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
```

```
# loop over the raw matches
for m in matches_lf1_lf:
  # ensure the distance is within a certain ratio of each
  # other (i.e. Lowe’s ratio test)
  if len(m) == 2 and m[0].distance < m[1].distance * ratio:
      #matches_1.append((m[0].trainIdx, m[0].queryIdx))
      matches_4.append(m[0])

print("Number of matches After Lowe's Ratio",len(matches_4))

matches_idx = np.array([m.queryIdx for m in matches_4])
imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
matches_idx = np.array([m.trainIdx for m in matches_4])
imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
'''
# Estimate homography 1
#Compute H1
# Estimate homography 1
#Compute H1
imm1_pts=np.empty((len(matches_4),2))
imm2_pts=np.empty((len(matches_4),2))
for i in range(0,len(matches_4)):
  m = matches_4[i]
  (a_x, a_y) = keypts[0][m.queryIdx].pt
  (b_x, b_y) = keypts[1][m.trainIdx].pt
  imm1_pts[i]=(a_x, a_y)
  imm2_pts[i]=(b_x, b_y)
H=compute_Homography(imm1_pts,imm2_pts)
#Robustly estimate Homography 1 using RANSAC
Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
'''



Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
print("Number of Robust matches",len(inlier_matchset))
print("\n")
'''
if len(inlier_matchset)<50:
  matches_4 = []
  ratio = 0.67
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])
  print("Number of matches After Lowe's Ratio New",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
```

```
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0064.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0063.JPG', '/content/drive/MyDrive
```

```
H_left_brisk = []
H_right_brisk = []

num_matches_brisk = []
num_good_matches_brisk = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_brisk[
  H_left_brisk.append(H_a)
  num_matches_brisk.append(matches)
  num_good_matches_brisk.append(gd_matches)

for j in tqdm(range(len(images_right))):
```

```
    if j==len(images_right)-1:
      break

    H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_bris
    H_right_brisk.append(H_a)
    #num_matches.append(matches)
    #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/61 [00:03<03:25,  3.43s/it]
Number of matches 35128
Number of matches After Lowe's Ratio 6689
Number of Robust matches 2415


  3%|▎          | 2/61 [00:07<03:31,  3.58s/it]
Number of matches 24778
Number of matches After Lowe's Ratio 5020
Number of Robust matches 1933


  5%|▍          | 3/61 [00:09<03:07,  3.24s/it]
Number of matches 23035
Number of matches After Lowe's Ratio 3966
Number of Robust matches 641


  7%|▋          | 4/61 [00:12<02:49,  2.97s/it]
Number of matches 25059
Number of matches After Lowe's Ratio 4426
Number of Robust matches 368


  8%|▊          | 5/61 [00:15<02:50,  3.05s/it]
Number of matches 30921
Number of matches After Lowe's Ratio 4775
Number of Robust matches 384


 10%|▉          | 6/61 [00:18<02:56,  3.21s/it]
Number of matches 26028
Number of matches After Lowe's Ratio 3604
Number of Robust matches 8


 11%|█          | 7/61 [00:21<02:49,  3.14s/it]
Number of matches 23435
Number of matches After Lowe's Ratio 4818
Number of Robust matches 1510


 13%|█▏         | 8/61 [00:24<02:44,  3.10s/it]
Number of matches 28302
Number of matches After Lowe's Ratio 5980
Number of Robust matches 1689


 15%|█▍         | 9/61 [00:28<02:45,  3.18s/it]
```

```
 Number of matches 26534
 Number of matches After Lowe's Ratio 5242
 Number of Robust matches 1454


  16%|██         | 10/61 [00:31<02:43,  3.21s/it]
 Number of matches 32280
 Number of matches After Lowe's Ratio 6646
 Number of Robust matches 1993
```

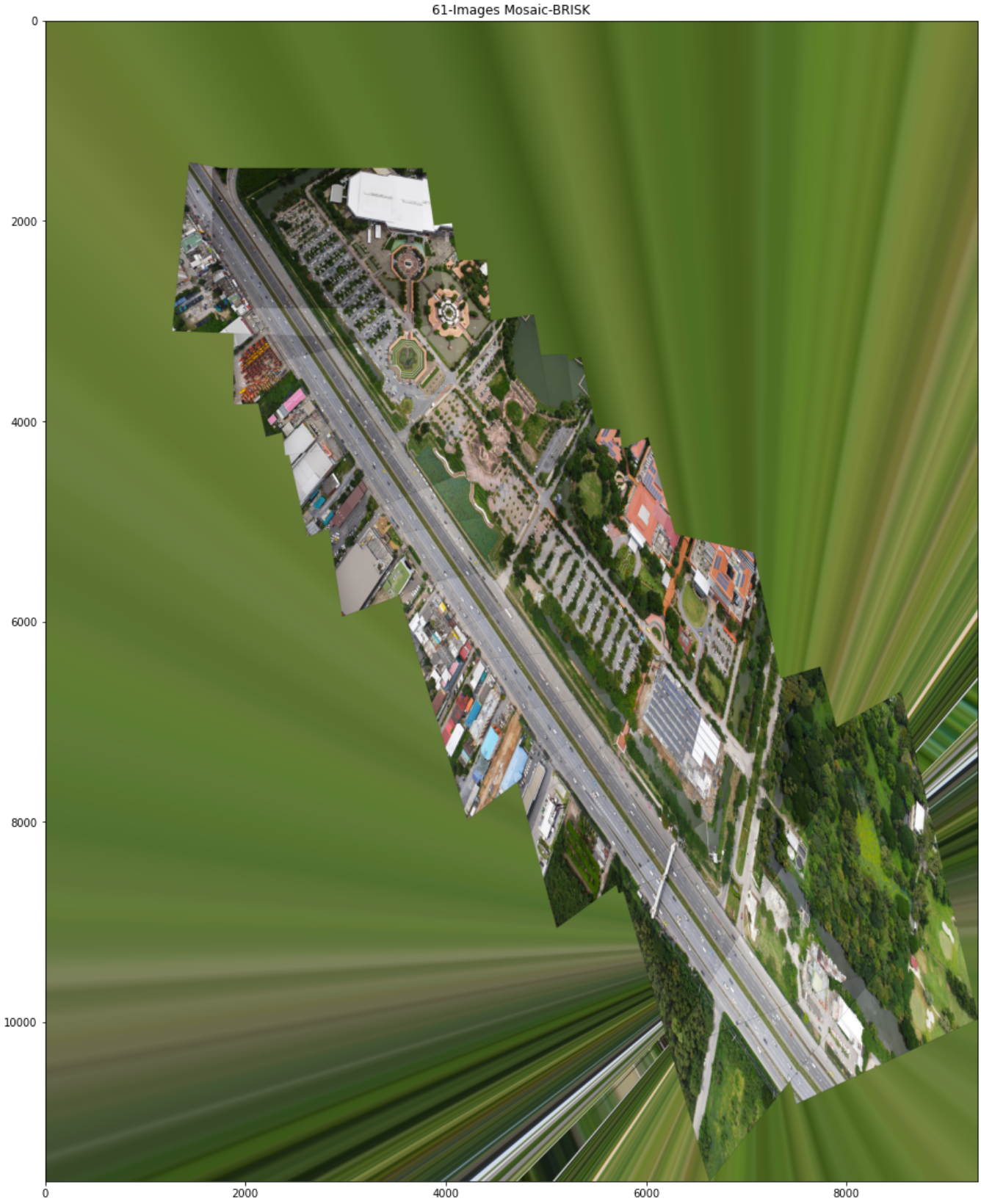
```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')
```

```
    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')
```

```
    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,
```

```
      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en


     Step1:Done
     Step2:Done


warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_brisk,xmax,xmin,yma


warp_imgs_all_brisk = final_steps_right_union(warp_imgs_left, images_right_bgr_no_enhance,H_r


     Step32:Done


fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_brisk , cv2.COLOR_BGR2RGB))
ax.set_title('61-Images Mosaic-BRISK')
```

```
Text(0.5, 1.0, '61-Images Mosaic-BRISK')
```




```
mser = cv2.MSER_create()
sift = cv2.xfeatures2d.SIFT_create()
```

```
sift = cv2.xfeatures2d.SIFT_create()

keypoints_all_left_mser = []
descriptors_all_left_mser = []
points_all_left_mser=[]

keypoints_all_right_mser = []
descriptors_all_right_mser = []
points_all_right_mser=[]

for imgs in tqdm(images_left_bgr_no_enhance):
  kpt = mser.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_left_mser.append(kpt)
  descriptors_all_left_mser.append(descrip)
  points_all_left_mser.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr_no_enhance):
  kpt = mser.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_mser.append(kpt)
  descriptors_all_right_mser.append(descrip)
  points_all_right_mser.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 61/61 [05:42<00:00,  5.62s/it]
100%|██████████| 61/61 [06:09<00:00,  6.05s/it]
```

```
#num_kps_sift = []
#num_kps_brisk = []
#num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
#num_kps_fast = []
#num_kps_freak = []
#num_kps_gftt = []
#num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))

#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

#for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
  #num_kps_agast.append(len(j))

#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))
```

```
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
  num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
  #num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  #num_kps_freak.append(len(j))

#for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
  #num_kps_gftt.append(len(j))

#for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  #num_kps_star.append(len(j))
```

```
100%|██████████| 122/122 [00:00<00:00, 176267.68it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
```

```
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])

  print("Number of matches After Lowe's Ratio",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
  matches_idx = np.array([m.trainIdx for m in matches_4])
  imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
  '''
  # Estimate homography 1
  #Compute H1
  # Estimate homography 1
  #Compute H1
  imm1_pts=np.empty((len(matches_4),2))
  imm2_pts=np.empty((len(matches_4),2))
  for i in range(0,len(matches_4)):
    m = matches_4[i]
    (a_x, a_y) = keypts[0][m.queryIdx].pt
    (b_x, b_y) = keypts[1][m.trainIdx].pt
    imm1_pts[i]=(a_x, a_y)
    imm2_pts[i]=(b_x, b_y)
  H=compute_Homography(imm1_pts,imm2_pts)
  #Robustly estimate Homography 1 using RANSAC
  Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
  '''
```

```
  Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
  inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
  print("Number of Robust matches",len(inlier_matchset))
  print("\n")
  '''
  if len(inlier_matchset)<50:
    matches_4 = []
    ratio = 0.67
    # loop over the raw matches
    for m in matches_lf1_lf:
      # ensure the distance is within a certain ratio of each
      # other (i.e. Lowe’s ratio test)
      if len(m) == 2 and m[0].distance < m[1].distance * ratio:
          #matches_1.append((m[0].trainIdx, m[0].queryIdx))
          matches_4.append(m[0])
    print("Number of matches After Lowe's Ratio New",len(matches_4))

    matches_idx = np.array([m.queryIdx for m in matches_4])
    imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
    matches_idx = np.array([m.trainIdx for m in matches_4])
    imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
    Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches New",len(inlier_matchset))
    print("\n")
    '''
  #H=compute_Homography(imm1_pts,imm2_pts)
  #Robustly estimate Homography 1 using RANSAC
  #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

  #global inlier_matchset

  if disp==True:
    dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
    displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

  return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0064.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0063.JPG', '/content/drive/MyDrive
```

```
H_left_mser = []
H_right_mser = []

num_matches_mser = []
num_good_matches_mser = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_mser[j
  H_left_mser.append(H_a)
  #num_matches_sift.append(matches)
  #num_good_matches_sift.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_mser
  H_right_mser.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/61 [00:00<00:16,  3.58it/s]
Number of matches 2578
Number of matches After Lowe's Ratio 791
Number of Robust matches 240


  3%|▎          | 2/61 [00:00<00:18,  3.21it/s]
Number of matches 2515
Number of matches After Lowe's Ratio 735
Number of Robust matches 152


  5%|▍          | 3/61 [00:01<00:18,  3.06it/s]
Number of matches 2573
Number of matches After Lowe's Ratio 489
Number of Robust matches 106


  7%|▋          | 4/61 [00:01<00:19,  2.93it/s]
Number of matches 2649
Number of matches After Lowe's Ratio 563
Number of Robust matches 73


  8%|▊          | 5/61 [00:01<00:20,  2.78it/s]
Number of matches 3077
```

```
 Number of matches After Lowe's Ratio 432
 Number of Robust matches 58


  10%|▉         | 6/61 [00:02<00:21,  2.59it/s]
 Number of matches 2731
 Number of matches After Lowe's Ratio 199
 Number of Robust matches 31


  11%|▉         | 7/61 [00:02<00:21,  2.50it/s]
 Number of matches 2847
 Number of matches After Lowe's Ratio 1011
 Number of Robust matches 219


  13%|▉         | 8/61 [00:03<00:21,  2.49it/s]
 Number of matches 2761
 Number of matches After Lowe's Ratio 359
 Number of Robust matches 80


  15%|▉         | 9/61 [00:03<00:21,  2.45it/s]
 Number of matches 2570
 Number of matches After Lowe's Ratio 679
 Number of Robust matches 143


  16%|▉         | 10/61 [00:03<00:20,  2.50it/s]
 Number of matches 2642
 Number of matches After Lowe's Ratio 396
 Number of Robust matches 74
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]
```

```
    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
```

```
      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):
```

```
    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en

 Step1:Done
```

```
      Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_mser,xmax,xmin,ymax
```

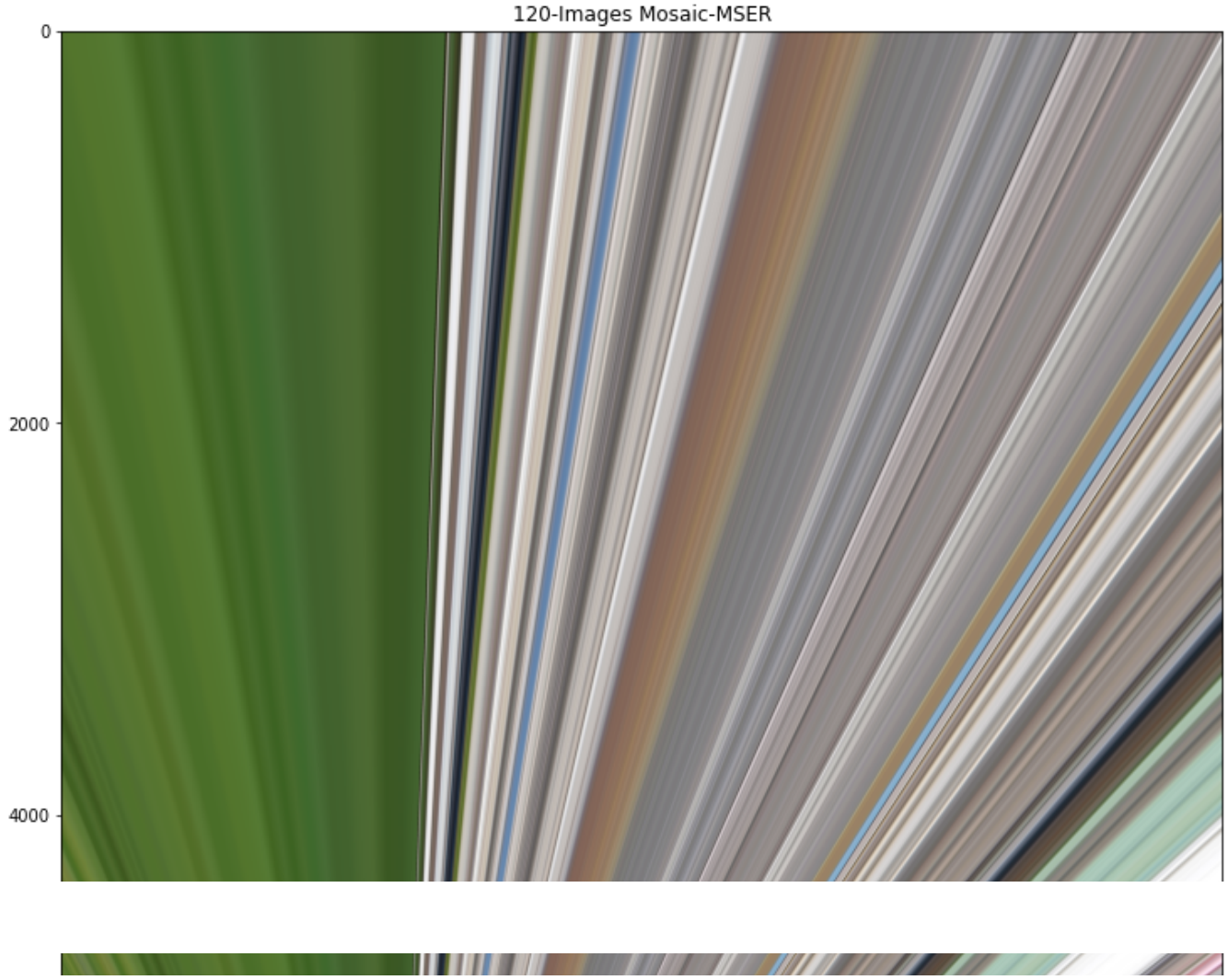
```
      Step31:Done
```

```
warp_imgs_all_mser = final_steps_right_union(warp_imgs_left,images_right_bgr_no_enhance,H_rig
```

```
      Step32:Done
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_mser , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-MSER')
```

```
Text(0.5, 1.0, '120-Images Mosaic-MSER')
```




```
agast = cv2.AgastFeatureDetector_create()
sift = cv2.xfeatures2d.SIFT_create()

keypoints_all_left_agast = []
descriptors_all_left_agast = []
points_all_left_agast=[]

keypoints_all_right_agast = []
descriptors_all_right_agast = []
points_all_right_agast=[]

for imgs in tqdm(images_left_bgr_no_enhance):
  kpt = agast.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_left_agast.append(kpt)
  descriptors_all_left_agast.append(descrip)
  points_all_left_agast.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr_no_enhance):
  kpt = agast.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_agast.append(kpt)
```

```
    keypoints_all_right_agast.append(kpt)
    descriptors_all_right_agast.append(descrip)
    points_all_right_agast.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 61/61 [09:18<00:00,  9.15s/it]
100%|██████████| 61/61 [08:32<00:00,  8.41s/it]
```

```
#num_kps_sift = []
#num_kps_brisk = []
num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
#num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
#num_kps_fast = []
#num_kps_freak = []
#num_kps_gftt = []
#num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))

#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
  num_kps_agast.append(len(j))

#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

#for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
#  num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
#  num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
```

```
    #num_kps_freak.append(len(j))

  #for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
  #  num_kps_gftt.append(len(j))

  #for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
    #num_kps_star.append(len(j))
```

```
100%|██████████| 122/122 [00:00<00:00, 82307.40it/s]
```

```
  def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
      #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
      #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

      # Estimate the homography between the matches using RANSAC
      H, inliers = cv2.findHomography(matched_pts1,
                                      matched_pts2,
                                      cv2.RANSAC, ransacReprojThreshold =thresh)
      inliers = inliers.flatten()
      return H, inliers


  def compute_homography_fast_other(matched_pts1, matched_pts2):
      #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
      #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

      # Estimate the homography between the matches using RANSAC
      H, inliers = cv2.findHomography(matched_pts1,
                                      matched_pts2,
                                      0)
      inliers = inliers.flatten()
      return H, inliers


  def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
    FLANN_INDEX_KDTREE = 2
    index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
    search_params = dict(checks=50)
    flann = cv2.FlannBasedMatcher(index_params, search_params)
    #flann = cv2.BFMatcher()

    lff1 = np.float32(descripts[0])
    lff = np.float32(descripts[1])


    matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

    print("\nNumber of matches",len(matches_lf1_lf))

    matches_4 = []
    ratio = ratio
    # loop over the raw matches
```

```
# loop over the raw matches
for m in matches_lf1_lf:
  # ensure the distance is within a certain ratio of each
  # other (i.e. Lowe’s ratio test)
  if len(m) == 2 and m[0].distance < m[1].distance * ratio:
      #matches_1.append((m[0].trainIdx, m[0].queryIdx))
      matches_4.append(m[0])

print("Number of matches After Lowe's Ratio",len(matches_4))

matches_idx = np.array([m.queryIdx for m in matches_4])
imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
matches_idx = np.array([m.trainIdx for m in matches_4])
imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
'''
# Estimate homography 1
#Compute H1
# Estimate homography 1
#Compute H1
imm1_pts=np.empty((len(matches_4),2))
imm2_pts=np.empty((len(matches_4),2))
for i in range(0,len(matches_4)):
  m = matches_4[i]
  (a_x, a_y) = keypts[0][m.queryIdx].pt
  (b_x, b_y) = keypts[1][m.trainIdx].pt
  imm1_pts[i]=(a_x, a_y)
  imm2_pts[i]=(b_x, b_y)
H=compute_Homography(imm1_pts,imm2_pts)
#Robustly estimate Homography 1 using RANSAC
Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
'''



Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
print("Number of Robust matches",len(inlier_matchset))
print("\n")
'''
if len(inlier_matchset)<50:
  matches_4 = []
  ratio = 0.67
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])
  print("Number of matches After Lowe's Ratio New",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
```

```
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0064.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0063.JPG', '/content/drive/MyDrive
```

```
H_left_agast = []
H_right_agast = []

num_matches_agast = []
num_good_matches_agast = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_agast[
  H_left_agast.append(H_a)
  #num_matches_sift.append(matches)
  #num_good_matches_sift.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
```

```
    if j==len(images_right)-1:
      break

    H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_agas
    H_right_agast.append(H_a)
    #num_matches.append(matches)
    #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/61 [00:32<32:47, 32.80s/it]
Number of matches 136160
Number of matches After Lowe's Ratio 20113
Number of Robust matches 13353


  3%|▎          | 2/61 [01:07<32:45, 33.32s/it]
Number of matches 120007
Number of matches After Lowe's Ratio 16054
Number of Robust matches 10551


  5%|▍          | 3/61 [01:37<31:09, 32.24s/it]
Number of matches 117876
Number of matches After Lowe's Ratio 6545
Number of Robust matches 3540


  7%|▋          | 4/61 [02:06<29:50, 31.42s/it]
Number of matches 123626
Number of matches After Lowe's Ratio 4772
Number of Robust matches 1776


  8%|▊          | 5/61 [02:38<29:24, 31.51s/it]
Number of matches 135893
Number of matches After Lowe's Ratio 1815
Number of Robust matches 683


 10%|▉          | 6/61 [03:10<29:06, 31.75s/it]
Number of matches 119233
Number of matches After Lowe's Ratio 132
Number of Robust matches 64



Number of matches 119944
Number of matches After Lowe's Ratio 14638
 11%|█          | 7/61 [03:40<28:12, 31.34s/it]Number of Robust matches 7731


 13%|█▏         | 8/61 [04:11<27:29, 31.13s/it]
Number of matches 127483
Number of matches After Lowe's Ratio 1461
Number of Robust matches 618


 15%|█▍         | 9/61 [04:43<27:07, 31.30s/it]
```

```
 Number of matches 120719
 Number of matches After Lowe's Ratio 4930
 Number of Robust matches 2477


  16%|██         | 10/61 [05:14<26:36, 31.30s/it]
 Number of matches 127159
 Number of matches After Lowe's Ratio 2256
 Number of Robust matches 1160
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')
```

```
    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')
```

```
    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,
```

```
      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

```
 Step1:Done
 Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_agast,xmax,xmin,yma



warp_imgs_all_agast = final_steps_right_union(warp_imgs_left, images_right_bgr_no_enhance,H_r



fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_agast , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-AGAST')
```

```
fast = cv2.FastFeatureDetector_create(20)
sift = cv2.xfeatures2d.SIFT_create()

keypoints_all_left_fast = []
descriptors_all_left_fast = []
points_all_left_fast=[]

keypoints_all_right_fast = []
descriptors_all_right_fast = []
points_all_right_fast=[]

for imgs in tqdm(images_left_bgr_no_enhance):
  kpt = fast.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_left_fast.append(kpt)
  descriptors_all_left_fast.append(descrip)
  points_all_left_fast.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr_no_enhance):
  kpt = fast.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_fast.append(kpt)
  descriptors_all_right_fast.append(descrip)
  points_all_right_fast.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
100%|██████████| 51/51 [02:58<00:00,  3.49s/it]
100%|██████████| 50/50 [02:56<00:00,  3.53s/it]
```

```
#num_kps_sift = []
#num_kps_brisk = []
#num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
#num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
num_kps_fast = []
#num_kps_freak = []
#num_kps_gftt = []
#num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))

#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

#for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
#  num_kps_agast.append(len(j))
```

```
#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

#for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
#  num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
  num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  #num_kps_freak.append(len(j))

#for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
#  num_kps_gftt.append(len(j))

#for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  #num_kps_star.append(len(j))
```

```
100%|██████████| 101/101 [00:00<00:00, 34508.37it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
```

```
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])

  print("Number of matches After Lowe's Ratio",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
  matches_idx = np.array([m.trainIdx for m in matches_4])
  imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
  '''
  # Estimate homography 1
  #Compute H1
  # Estimate homography 1
  #Compute H1
  imm1_pts=np.empty((len(matches_4),2))
  imm2_pts=np.empty((len(matches_4),2))
  for i in range(0,len(matches_4)):
    m = matches_4[i]
    (a_x, a_y) = keypts[0][m.queryIdx].pt
    (b_x, b_y) = keypts[1][m.trainIdx].pt
    imm1_pts[i]=(a_x, a_y)
    imm2_pts[i]=(b_x, b_y)
  H=compute_Homography(imm1_pts,imm2_pts)
  #Robustly estimate Homography 1 using RANSAC
  Hn, best_inliers=RANSAC_alg(keypts[0],keypts[1], matches_4, nRANSAC=1000, RANSACthresh=6)
```

```
    ''' best_inliers, RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
    '''



    Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches",len(inlier_matchset))
    print("\n")
    '''
    if len(inlier_matchset)<50:
      matches_4 = []
      ratio = 0.67
      # loop over the raw matches
      for m in matches_lf1_lf:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe’s ratio test)
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])
      print("Number of matches After Lowe's Ratio New",len(matches_4))

      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
H_left_fast = []
H_right_fast = []

num_matches_fast = []
num_good_matches_fast = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_fast[j
  H_left_fast.append(H_a)
  #num_matches_sift.append(matches)
  #num_good_matches_sift.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_fast
  H_right_fast.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▏          | 1/51 [00:09<08:14,  9.89s/it]
Number of matches 39843
Number of matches After Lowe's Ratio 485
Number of Robust matches 284


  4%|▍          | 2/51 [00:16<07:21,  9.01s/it]
Number of matches 52528
Number of matches After Lowe's Ratio 497
Number of Robust matches 358


  6%|▌          | 3/51 [00:24<06:58,  8.71s/it]
Number of matches 34339
Number of matches After Lowe's Ratio 122
Number of Robust matches 80


  8%|▊          | 4/51 [00:30<06:08,  7.83s/it]
Number of matches 47210
Number of matches After Lowe's Ratio 989
Number of Robust matches 847
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
```

```
        pts_ = cv2.perspectiveTransform(pts, H_trans)
        pts_left_transformed.append(pts_)

      for j,pts in enumerate(pts_right):
        if j==0:
          H_trans = H_right[j]
        else:
          H_trans = H_trans@H_right[j]
        pts_ = cv2.perspectiveTransform(pts, H_trans)
        pts_right_transformed.append(pts_)


      print('Step1:Done')


      #pts = np.concatenate((pts1, pts2_), axis=0)

      pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

      [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
      [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
      t = [-xmin, -ymin]
      Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

      print('Step2:Done')


      return xmax,xmin,ymax,ymin,t,h,w,Ht


  def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

      warp_imgs_left = []


      for j,H in enumerate(H_left):
        if j==0:
          H_trans = Ht@H
        else:
          H_trans = H_trans@H
        result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

        if j==0:
          result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

        warp_imgs_left.append(result)

      print('Step31:Done')

      return warp_imgs_left

  def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):
```

```
    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
```

```
          H_trans = H_trans@H
        input_img = images_left[j+1]
        result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

        cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
        warp_img_init_curr = result

        if j==0:
          result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
          warp_img_init_prev = result
          continue

        black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

        warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

      print('Step31:Done')

      return warp_img_init_prev

  def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

      for j,H in enumerate(H_right):
        if j==0:
          H_trans = Ht@H
        else:
          H_trans = H_trans@H
        input_img = images_right[j+1]
        result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

        cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
        warp_img_init_curr = result

        black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

        warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

      print('Step32:Done')

      return warp_img_prev


  xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en

       Step1:Done
       Step2:Done


  warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_fast,xmax,xmin,ymax


  warp_imgs_all_fast = final_steps_right_union(warp_imgs_left, images_right_bgr_no_enhance,H_ri
```

```
fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_fast , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-FAST')


gftt = cv2.GFTTDetector_create()
sift = cv2.xfeatures2d.SIFT_create()

keypoints_all_left_gftt = []
descriptors_all_left_gftt = []
points_all_left_gftt=[]

keypoints_all_right_gftt = []
descriptors_all_right_gftt = []
points_all_right_gftt=[]

for imgs in tqdm(images_left_bgr_no_enhance):
  kpt = gftt.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_left_gftt.append(kpt)
  descriptors_all_left_gftt.append(descrip)
  points_all_left_gftt.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr_no_enhance):
  kpt = gftt.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_gftt.append(kpt)
  descriptors_all_right_gftt.append(descrip)
  points_all_right_gftt.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

     100%|██████████| 56/56 [00:13<00:00,  4.05it/s]
     100%|██████████| 55/55 [00:13<00:00,  3.99it/s]


#num_kps_sift = []
#num_kps_brisk = []
#num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
#num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
#num_kps_fast = []
#num_kps_freak = []
num_kps_gftt = []
#num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))
```

```
#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

#for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
#  num_kps_agast.append(len(j))

#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

#for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
#  num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
#  num_kps_fast.append(len(j))

#for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  #num_kps_freak.append(len(j))

for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
  num_kps_gftt.append(len(j))

#for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  #num_kps_star.append(len(j))
```

```
100%|██████████| 111/111 [00:00<00:00, 47405.33it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
```

```
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])

  print("Number of matches After Lowe's Ratio",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
  matches_idx = np.array([m.trainIdx for m in matches_4])
  imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
  '''
  # Estimate homography 1
  #Compute H1
  # Estimate homography 1
  #Compute H1
  imm1_pts=np.empty((len(matches_4),2))
  imm2_pts=np.empty((len(matches_4),2))
  for i in range(0,len(matches_4)):
    m = matches_4[i]
    (a,x, a,y) = keypts[0][m.queryIdx].pt
```

```
      (a_x, a_y) = keypts[0][m.queryIdx].pt
      (b_x, b_y) = keypts[1][m.trainIdx].pt
      imm1_pts[i]=(a_x, a_y)
      imm2_pts[i]=(b_x, b_y)
    H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
    '''



    Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
    inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
    print("Number of Robust matches",len(inlier_matchset))
    print("\n")
    '''
    if len(inlier_matchset)<50:
      matches_4 = []
      ratio = 0.67
      # loop over the raw matches
      for m in matches_lf1_lf:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe’s ratio test)
        if len(m) == 2 and m[0].distance < m[1].distance * ratio:
            #matches_1.append((m[0].trainIdx, m[0].queryIdx))
            matches_4.append(m[0])
      print("Number of matches After Lowe's Ratio New",len(matches_4))

      matches_idx = np.array([m.queryIdx for m in matches_4])
      imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
      matches_idx = np.array([m.trainIdx for m in matches_4])
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)
```

```
print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0059.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0059.JPG', '/content/drive/MyDrive
```

```
H_left_gftt = []
H_right_gftt = []

num_matches_gftt = []
num_good_matches_gftt = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_gftt[j
  H_left_gftt.append(H_a)
  #num_matches_sift.append(matches)
  #num_good_matches_sift.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_gftt
  H_right_gftt.append(H_a)
  #num_matches.append(matches)
  #num_good_matches.append(gd_matches)
```

```
  2%|▌          | 1/56 [00:00<00:08,  6.76it/s]
Number of matches 1000
Number of matches After Lowe's Ratio 32
Number of Robust matches 5



Number of matches 1000
Number of matches After Lowe's Ratio 306
Number of Robust matches 187


  7%|▋          | 4/56 [00:00<00:06,  7.89it/s]
Number of matches 1000
Number of matches After Lowe's Ratio 165
Number of Robust matches 94
```

```
 Number of matches 1000
 Number of matches After Lowe's Ratio 180
 Number of Robust matches 97


  11%|▉         | 6/56 [00:00<00:05,  8.35it/s]
 Number of matches 1000
 Number of matches After Lowe's Ratio 128
 Number of Robust matches 61



 Number of matches 1000
 Number of matches After Lowe's Ratio 208
 Number of Robust matches 124


  12%|▉         | 7/56 [00:00<00:05,  8.78it/s]
 Number of matches 1000
 Number of matches After Lowe's Ratio 177
 Number of Robust matches 126



 Number of matches 1000
 Number of matches After Lowe's Ratio 157
 Number of Robust matches 117


  18%|█▊        | 10/56 [00:01<00:05,  8.84it/s]
 Number of matches 1000
 Number of matches After Lowe's Ratio 278
 Number of Robust matches 238



 Number of matches 1000
 Number of matches After Lowe's Ratio 75
 Number of Robust matches 25
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)
```

```
    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')


    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
```

```
            H_trans = Ht@H
          else:
            H_trans = H_trans@H
          result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

          if j==0:
            result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

          warp_imgs_left.append(result)

        print('Step31:Done')

        return warp_imgs_left

    def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

        warp_imgs_right = []

        for j,H in enumerate(H_right):
          if j==0:
            H_trans = Ht@H
          else:
            H_trans = H_trans@H
          result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

          warp_imgs_right.append(result)

        print('Step32:Done')

        return warp_imgs_right

    def final_steps_union(warp_imgs_left,warp_imgs_right):
        #Union

        warp_images_all = warp_imgs_left + warp_imgs_right

        warp_img_init = warp_images_all[0]



        #warp_final_all=[]

        for j,warp_img in enumerate(warp_images_all):
          if j==len(warp_images_all)-1:
            break
          black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

          warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

          #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
          #warp_img_init = warp_final
          #warp_final_all.append(warp_final)
```

```
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]
```

```
    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

```
 Step1:Done
 Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_gftt,xmax,xmin,ymax


warp_imgs_all_gftt = final_steps_right_union(warp_imgs_left, images_right_bgr_no_enhance,H_ri


fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_gftt , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-GFTT')
```



```
Threshl=60;
Octaves=8;
#PatternScales=1.0f;
brisk = cv2.BRISK_create(Threshl,Octaves)

freak = cv2.xfeatures2d.FREAK_create()
keypoints_all_left_freak = []
descriptors_all_left_freak = []
points_all_left_freak=[]

keypoints_all_right_freak = []
descriptors_all_right_freak = []
points_all_right_freak=[]


for imgs in tqdm(images_left_bgr):
  kpt = brisk.detect(imgs)
  kpt,descrip =  freak.compute(imgs, kpt)
  keypoints_all_left_freak.append(kpt)
  descriptors_all_left_freak.append(descrip)
  points_all_left_freak.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for imgs in tqdm(images_right_bgr):
  kpt = brisk.detect(imgs,None)
  kpt,descrip =  freak.compute(imgs, kpt)
  keypoints_all_right_freak.append(kpt)
  descriptors_all_right_freak.append(descrip)
```

```
  points_all_right_freak.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))
```

```
    100%|██████████| 51/51 [00:41<00:00,  1.21it/s]
    100%|██████████| 50/50 [00:38<00:00,  1.29it/s]
```

```
#num_kps_sift = []
#num_kps_brisk = []
#num_kps_agast = []
#num_kps_kaze = []
#num_kps_akaze = []
#num_kps_orb = []
#num_kps_mser = []
#num_kps_daisy = []
#num_kps_surfsift = []
#num_kps_fast = []
num_kps_freak = []
#num_kps_gftt = []
#num_kps_star = []

#for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift):
#  num_kps_sift.append(len(j))

#for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk):
  #num_kps_brisk.append(len(j))

#for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast):
#  num_kps_agast.append(len(j))

#for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze):
#  num_kps_kaze.append(len(j))

#for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze):
  #num_kps_akaze.append(len(j))

#for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb):
  #num_kps_orb.append(len(j))

#for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser):
#  num_kps_mser.append(len(j))

#for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy):
#  num_kps_daisy.append(len(j))

#for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift):
#  num_kps_surfsift.append(len(j))

#for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast):
#  num_kps_fast.append(len(j))

for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak):
  num_kps_freak.append(len(j))
```

```
#for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt):
 # num_kps_gftt.append(len(j))

#for j in tqdm(keypoints_all_left_star + keypoints_all_right_star):
  #num_kps_star.append(len(j))
```

```
100%|██████████| 101/101 [00:00<00:00, 126041.27it/s]
```

```
def compute_homography_fast(matched_pts1, matched_pts2,thresh=4):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    cv2.RANSAC, ransacReprojThreshold =thresh)
    inliers = inliers.flatten()
    return H, inliers


def compute_homography_fast_other(matched_pts1, matched_pts2):
    #matched_pts1 = cv2.KeyPoint_convert(matched_kp1)
    #matched_pts2 = cv2.KeyPoint_convert(matched_kp2)

    # Estimate the homography between the matches using RANSAC
    H, inliers = cv2.findHomography(matched_pts1,
                                    matched_pts2,
                                    0)
    inliers = inliers.flatten()
    return H, inliers


def get_Hmatrix(imgs,keypts,pts,descripts,ratio=0.8,thresh=4,disp=False):
  FLANN_INDEX_KDTREE = 2
  index_params = dict(algorithm=FLANN_INDEX_KDTREE, trees=5)
  search_params = dict(checks=50)
  flann = cv2.FlannBasedMatcher(index_params, search_params)
  #flann = cv2.BFMatcher()

  lff1 = np.float32(descripts[0])
  lff = np.float32(descripts[1])


  matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)

  print("\nNumber of matches",len(matches_lf1_lf))

  matches_4 = []
  ratio = ratio
  # loop over the raw matches
  for m in matches_lf1_lf:
```

```
  # ensure the distance is within a certain ratio of each
  # other (i.e. Lowe’s ratio test)
  if len(m) == 2 and m[0].distance < m[1].distance * ratio:
      #matches_1.append((m[0].trainIdx, m[0].queryIdx))
      matches_4.append(m[0])

print("Number of matches After Lowe's Ratio",len(matches_4))

matches_idx = np.array([m.queryIdx for m in matches_4])
imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
matches_idx = np.array([m.trainIdx for m in matches_4])
imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
'''
# Estimate homography 1
#Compute H1
# Estimate homography 1
#Compute H1
imm1_pts=np.empty((len(matches_4),2))
imm2_pts=np.empty((len(matches_4),2))
for i in range(0,len(matches_4)):
  m = matches_4[i]
  (a_x, a_y) = keypts[0][m.queryIdx].pt
  (b_x, b_y) = keypts[1][m.trainIdx].pt
  imm1_pts[i]=(a_x, a_y)
  imm2_pts[i]=(b_x, b_y)
H=compute_Homography(imm1_pts,imm2_pts)
#Robustly estimate Homography 1 using RANSAC
Hn, best_inliers=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1000, RANSACthresh=6)
'''



Hn,inliers = compute_homography_fast(imm1_pts,imm2_pts,thresh)
inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
print("Number of Robust matches",len(inlier_matchset))
print("\n")
'''
if len(inlier_matchset)<50:
  matches_4 = []
  ratio = 0.67
  # loop over the raw matches
  for m in matches_lf1_lf:
    # ensure the distance is within a certain ratio of each
    # other (i.e. Lowe’s ratio test)
    if len(m) == 2 and m[0].distance < m[1].distance * ratio:
        #matches_1.append((m[0].trainIdx, m[0].queryIdx))
        matches_4.append(m[0])
  print("Number of matches After Lowe's Ratio New",len(matches_4))

  matches_idx = np.array([m.queryIdx for m in matches_4])
  imm1_pts = np.array([keypts[0][idx].pt for idx in matches_idx])
  matches_idx = np.array([m.trainIdx for m in matches_4])
  imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
```

```
      imm2_pts = np.array([keypts[1][idx].pt for idx in matches_idx])
      Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
      inlier_matchset = np.array(matches_4)[inliers.astype(bool)].tolist()
      print("Number of Robust matches New",len(inlier_matchset))
      print("\n")
      '''
    #H=compute_Homography(imm1_pts,imm2_pts)
    #Robustly estimate Homography 1 using RANSAC
    #Hn=RANSAC_alg(keypts[0] ,keypts[1], matches_4,  nRANSAC=1500, RANSACthresh=6)

    #global inlier_matchset

    if disp==True:
      dispimg1=cv2.drawMatches(imgs[0], keypts[0], imgs[1], keypts[1], inlier_matchset, None,fl
      displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')

    return Hn/Hn[2,2], len(matches_lf1_lf), len(inlier_matchset)


from functools import partial
from tqdm import tqdm
tqdm = partial(tqdm, position=0, leave=True)


print(left_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
print(right_files_path)
```

```
['/content/drive/MyDrive/RGB-img/img/IX-11-01917_0004_0054.JPG', '/content/drive/MyDrive
```

```
H_left_freak = []
H_right_freak = []

num_matches_freak = []
num_good_matches_freak = []

for j in tqdm(range(len(images_left))):
  if j==len(images_left)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_freak[
  H_left_freak.append(H_a)
  num_matches_freak.append(matches)
  num_good_matches_freak.append(gd_matches)

for j in tqdm(range(len(images_right))):
  if j==len(images_right)-1:
    break
```

```
H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_frea
H_right_freak.append(H_a)
num_matches_freak.append(matches)
num_good_matches_freak.append(gd_matches)
```

```
  2%|▏          | 1/51 [00:02<01:43,  2.08s/it]
Number of matches 20799
Number of matches After Lowe's Ratio 2054
Number of Robust matches 550


  4%|▍          | 2/51 [00:03<01:36,  1.96s/it]
Number of matches 28885
Number of matches After Lowe's Ratio 2887
Number of Robust matches 1185


  6%|▌          | 3/51 [00:05<01:35,  1.99s/it]
Number of matches 24714
Number of matches After Lowe's Ratio 2349
Number of Robust matches 768


  8%|▊          | 4/51 [00:07<01:32,  1.97s/it]
Number of matches 30963
Number of matches After Lowe's Ratio 3633
Number of Robust matches 1577


 10%|▉          | 5/51 [00:10<01:41,  2.20s/it]
Number of matches 30334
Number of matches After Lowe's Ratio 3558
Number of Robust matches 1723


 12%|█▏         | 6/51 [00:13<01:47,  2.38s/it]
Number of matches 35225
Number of matches After Lowe's Ratio 3888
Number of Robust matches 1560


 14%|█▎         | 7/51 [00:16<01:50,  2.51s/it]
Number of matches 34588
Number of matches After Lowe's Ratio 4538
Number of Robust matches 2613


 16%|█▌         | 8/51 [00:19<01:54,  2.66s/it]
Number of matches 32541
Number of matches After Lowe's Ratio 3919
Number of Robust matches 1821


 18%|█▋         | 9/51 [00:21<01:51,  2.66s/it]
Number of matches 28721
```

```
 Number of matches After Lowe's Ratio 3637
 Number of Robust matches 1966


  20%|██        | 10/51 [00:24<01:47,  2.61s/it]
 Number of matches 30225
 Number of matches After Lowe's Ratio 3772
 Number of Robust matches 1792
```

```
def warpnImages(images_left, images_right,H_left,H_right):
    #img1-centre,img2-left,img3-right

    h, w = images_left[0].shape[:2]

    pts_left = []
    pts_right = []

    pts_centre = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)

    for j in range(len(H_left)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_left.append(pts)

    for j in range(len(H_right)):
      pts = np.float32([[0, 0], [0, h], [w, h], [w, 0]]).reshape(-1, 1, 2)
      pts_right.append(pts)

    pts_left_transformed=[]
    pts_right_transformed=[]



    for j,pts in enumerate(pts_left):
      if j==0:
        H_trans = H_left[j]
      else:
        H_trans = H_trans@H_left[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_left_transformed.append(pts_)

    for j,pts in enumerate(pts_right):
      if j==0:
        H_trans = H_right[j]
      else:
        H_trans = H_trans@H_right[j]
      pts_ = cv2.perspectiveTransform(pts, H_trans)
      pts_right_transformed.append(pts_)


    print('Step1:Done')
```

```
    #pts = np.concatenate((pts1, pts2_), axis=0)

    pts_concat = np.concatenate((pts_centre,np.concatenate(np.array(pts_left_transformed),axi

    [xmin, ymin] = np.int32(pts_concat.min(axis=0).ravel() - 0.5)
    [xmax, ymax] = np.int32(pts_concat.max(axis=0).ravel() + 0.5)
    t = [-xmin, -ymin]
    Ht = np.array([[1, 0, t[0]], [0, 1, t[1]], [0, 0, 1]])  # translate

    print('Step2:Done')


    return xmax,xmin,ymax,ymin,t,h,w,Ht


def final_steps_left(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_left = []


    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_left[j+1], H_trans, (xmax-xmin, ymax-ymin))

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]

      warp_imgs_left.append(result)

    print('Step31:Done')

    return warp_imgs_left

def final_steps_right(images_left,images_right,H_left,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    warp_imgs_right = []

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      result = cv2.warpPerspective(images_right[j+1], H_trans, (xmax-xmin, ymax-ymin))

      warp_imgs_right.append(result)

    print('Step32:Done')

    return warp_imgs_right
```

```
    return warp_imgs_right

def final_steps_union(warp_imgs_left,warp_imgs_right):
    #Union

    warp_images_all = warp_imgs_left + warp_imgs_right

    warp_img_init = warp_images_all[0]



    #warp_final_all=[]

    for j,warp_img in enumerate(warp_images_all):
      if j==len(warp_images_all)-1:
        break
      black_pixels = np.where((warp_img_init[:, :, 0] == 0) & (warp_img_init[:, :, 1] == 0) &

      warp_img_init[black_pixels] = warp_images_all[j+1][black_pixels]

      #warp_final = np.maximum(warp_img_init,warp_images_all[j+1])
      #warp_img_init = warp_final
      #warp_final_all.append(warp_final)

    print('Step4:Done')


    return warp_img_init


def final_steps_left_union(images_left,H_left,xmax,xmin,ymax,ymin,t,h,w,Ht):



    for j,H in enumerate(H_left):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_left[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      if j==0:
        result[t[1]:h+t[1], t[0]:w+t[0]] = images_left[0]
        warp_img_init_prev = result
        continue

      black_pixels = np.where((warp_img_init_prev[:, :, 0] == 0) & (warp_img_init_prev[:, :,

      warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]
```

```
        warp_img_init_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step31:Done')

    return warp_img_init_prev

def final_steps_right_union(warp_img_prev,images_right,H_right,xmax,xmin,ymax,ymin,t,h,w,Ht):

    for j,H in enumerate(H_right):
      if j==0:
        H_trans = Ht@H
      else:
        H_trans = H_trans@H
      input_img = images_right[j+1]
      result = np.zeros((ymax-ymin,xmax-xmin,3),dtype='uint8')

      cv2.warpPerspective(src = np.uint8(input_img), M = H_trans, dsize = (xmax-xmin, ymax-ym
      warp_img_init_curr = result

      black_pixels = np.where((warp_img_prev[:, :, 0] == 0) & (warp_img_prev[:, :, 1] == 0) &

      warp_img_prev[black_pixels] = warp_img_init_curr[black_pixels]

    print('Step32:Done')

    return warp_img_prev


xmax,xmin,ymax,ymin,t,h,w,Ht = warpnImages(images_left_bgr_no_enhance, images_right_bgr_no_en
```

```
 Step1:Done
 Step2:Done
```

```
warp_imgs_left = final_steps_left_union(images_left_bgr_no_enhance,H_left_freak,xmax,xmin,yma


warp_imgs_all_freak = final_steps_right_union(warp_imgs_left, images_right_bgr_no_enhance,H_r


fig,ax =plt.subplots()
fig.set_size_inches(20,20)
ax.imshow(cv2.cvtColor(warp_imgs_all_freak , cv2.COLOR_BGR2RGB))
ax.set_title('120-Images Mosaic-FREAK')
```

8s completed at 22:38