```
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
import h5py as h5

#cuda_output = !ldconfig -p|grep cudart.so|sed -e 's/.*\.\([0-9]*\)\.\([0-9]*\)$/cu\1\2/'
#accelerator = cuda_output[0] if exists('/dev/nvidia0') else 'cpu'

#print("Accelerator type = ",accelerator)
#print("Pytorch verision: ", torch.__version__)
```

```
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.mount("/content/drive", force_remount=True).
```

```
#!pip install ipython-autotime

#%load_ext autotime
```

```
!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-packages (3.4.2.17)
     Requirement already satisfied: numpy>=1.14.5 in /usr/local/lib/python3.7/dist-packages (from opencv-python==3.4.2.17) (1.19.5)
     Requirement already satisfied: opencv-contrib-python==3.4.2.17 in /usr/local/lib/python3.7/dist-packages (3.4.2.17)
     Requirement already satisfied: numpy>=1.14.5 in /usr/local/lib/python3.7/dist-packages (from opencv-contrib-python==3.4.2.17) (1.19.5)
```

```
#!pip install opencv-python==4.4.0.44
#!pip install opencv-contrib-python==4.4.0.44
```

```


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,index)]



def compute_Homography(im1_pts,im2_pts):
```

```
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]
    #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 respect to z
    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 estimates
        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
```

```
tqdm = partial(tqdm, position=0, leave=True)
tqdm = partial(tqdm, position=0, leave=True)
```

```
files_all=[]
for file in os.listdir("/content/drive/My Drive/Uni_img"):
    if file.endswith(".JPG"):
      files_all.append(file)


files_all.sort()
folder_path = '/content/drive/My Drive/Uni_img/'

#centre_file = folder_path + files_all[50]
left_files_path_rev = []
right_files_path = []


#Change this according to your dataset split

for file in files_all[:int(len(files_all)/2)+1]:
  left_files_path_rev.append(folder_path + file)

left_files_path = left_files_path_rev[::-1]

for file in files_all[int(len(files_all)/2):]:
  right_files_path.append(folder_path + file)
```

```
from multiprocessing import Pool
```

```
#pool = Pool(4)

#images_left_bgr = pool.map(get_images, left_files_path)
```

```
import multiprocessing
print(multiprocessing.cpu_count())
```

```
    4
```

```
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_CUBIC )
  images_right.append(cv2.cvtColor(right_img, cv2.COLOR_BGR2GRAY).astype('float32')/255.)
  images_right_bgr.append(right_img)
```

```
100%|██████████| 6/6 [00:03<00:00,  1.57it/s]
100%|██████████| 6/6 [00:03<00:00,  1.60it/s]
```

```
f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=images_left_bgr + images_right_bgr)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/all_images_bgr_sift_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.2757728099822998 [s] ... size 105.842048 MB
```

```
f=h5.File('drive/MyDrive/all_images_gray_sift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=images_left + images_right)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/all_images_gray_sift_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.728400707244873 [s] ... size 141.122048 MB
```

```
del images_left_bgr,images_right_bgr
```

```
#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_CUBIC)
#  images_right_bgr_no_enhance.append(right_img)
```

```
from timeit import default_timer as timer
```

```
time_all = []
```

```
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_briefstar = []
num_kps_surf = []
num_kps_rootsift = []
num_kps_superpoint = []
```

BRISK

```
Threshl=60;
Octaves=6;
#PatternScales=1.0f;

start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:04<00:00,  1.37it/s]
     100%|██████████| 6/6 [00:04<00:00,  1.43it/s]
```

```
for j in tqdm(keypoints_all_left_brisk + keypoints_all_right_brisk[1:]):
  num_kps_brisk.append(len(j))
```

```
all_feat_brisk_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_brisk):
  all_feat_brisk_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_brisk[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_brisk_left_each.append(temp)
  all_feat_brisk_left.append(all_feat_brisk_left_each)
```

```
all_feat_brisk_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_brisk):
  all_feat_brisk_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_brisk[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_brisk_right_each.append(temp)
  all_feat_brisk_right.append(all_feat_brisk_right_each)
```

```
del keypoints_all_left_brisk, keypoints_all_right_brisk, descriptors_all_left_brisk, descriptors_all_right_brisk
```

```
import pickle
Fdb = open('all_feat_brisk_left.dat', 'wb')
pickle.dump(all_feat_brisk_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_brisk_right.dat', 'wb')
pickle.dump(all_feat_brisk_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_brisk_left, all_feat_brisk_right
```

ORB

```
orb = cv2.ORB_create(20000)

start = timer()


keypoints_all_left_orb = []
descriptors_all_left_orb = []
points_all_left_orb=[]

keypoints_all_right_orb = []
descriptors_all_right_orb = []
points_all_right_orb=[]
```

```
points_all_right_orb=[]

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  kpt = orb.detect(imgs,None)
  kpt,descrip =  orb.compute(imgs, kpt)
  keypoints_all_left_orb.append(kpt)
  descriptors_all_left_orb.append(descrip)
  #points_all_left_orb.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  kpt = orb.detect(imgs,None)
  kpt,descrip =  orb.compute(imgs, kpt)
  keypoints_all_right_orb.append(kpt)
  descriptors_all_right_orb.append(descrip)
  #points_all_right_orb.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:01<00:00,  3.79it/s]
     100%|██████████| 6/6 [00:01<00:00,  5.58it/s]
```

```
for j in tqdm(keypoints_all_left_orb + keypoints_all_right_orb[1:]):
  num_kps_orb.append(len(j))
```

```
all_feat_orb_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_orb):
  all_feat_orb_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_orb[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_orb_left_each.append(temp)
  all_feat_orb_left.append(all_feat_orb_left_each)
```

```
all_feat_orb_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_orb):
  all_feat_orb_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_orb[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_orb_right_each.append(temp)
  all_feat_orb_right.append(all_feat_orb_right_each)
```

```
del keypoints_all_left_orb, keypoints_all_right_orb, descriptors_all_left_orb, descriptors_all_right_orb
```

```
import pickle
Fdb = open('all_feat_orb_left.dat', 'wb')
pickle.dump(all_feat_orb_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_orb_right.dat', 'wb')
pickle.dump(all_feat_orb_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_orb_left, all_feat_orb_right
```

KAZE

```
start = timer()

kaze = cv2.KAZE_create()


keypoints_all_left_kaze = []
descriptors_all_left_kaze = []
points_all_left_kaze=[]

keypoints_all_right_kaze = []
descriptors_all_right_kaze = []
points_all_right_kaze=[]

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  kpt = kaze.detect(imgs,None)
  kpt,descrip =  kaze.compute(imgs, kpt)
  keypoints_all_left_kaze.append(kpt)
  descriptors_all_left_kaze.append(descrip)
  #points_all_left_kaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  kpt = kaze.detect(imgs,None)
  kpt,descrip =  kaze.compute(imgs, kpt)
  keypoints_all_right_kaze.append(kpt)
  descriptors_all_right_kaze.append(descrip)
  #points_all_right_kaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:25<00:00,  4.24s/it]
     100%|██████████| 6/6 [00:25<00:00,  4.22s/it]
```

```


for j in tqdm(keypoints_all_left_kaze + keypoints_all_right_kaze[1:]):
  num_kps_kaze.append(len(j))
```

```
all_feat_kaze_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_kaze):
  all_feat_kaze_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_kaze[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_kaze_left_each.append(temp)
  all_feat_kaze_left.append(all_feat_kaze_left_each)
```

```
all_feat_kaze_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_kaze):
  all_feat_kaze_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_kaze[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_kaze_right_each.append(temp)
  all_feat_kaze_right.append(all_feat_kaze_right_each)
```

```
del keypoints_all_left_kaze, keypoints_all_right_kaze, descriptors_all_left_kaze, descriptors_all_right_kaze
```

```
import pickle
Fdb = open('all_feat_kaze_left.dat', 'wb')
pickle.dump(all_feat_kaze_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_kaze_right.dat', 'wb')
pickle.dump(all_feat_kaze_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_kaze_left, all_feat_kaze_right
```

AKAZE

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

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:04<00:00,  1.37it/s]
     100%|██████████| 6/6 [00:04<00:00,  1.39it/s]
```

```
for j in tqdm(keypoints_all_left_akaze + keypoints_all_right_akaze[1:]):
  num_kps_akaze.append(len(j))
```

```
all_feat_akaze_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_akaze):
  all_feat_akaze_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_akaze[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_akaze_left_each.append(temp)
  all_feat_akaze_left.append(all_feat_akaze_left_each)
```

```
all_feat_akaze_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_akaze):
  all_feat_akaze_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_akaze[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_akaze_right_each.append(temp)
  all_feat_akaze_right.append(all_feat_akaze_right_each)
```

```
del keypoints_all_left_akaze, keypoints_all_right_akaze, descriptors_all_left_akaze, descriptors_all_right_akaze
```

```
import pickle
Fdb = open('all_feat_akaze_left.dat', 'wb')
pickle.dump(all_feat_akaze_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_akaze_right.dat', 'wb')
pickle.dump(all_feat_akaze_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_akaze_left, all_feat_akaze_right
```

STAR + BRIEF

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:00<00:00,  7.25it/s]
     100%|██████████| 6/6 [00:00<00:00,  7.32it/s]
```

```
for j in tqdm(keypoints_all_left_star + keypoints_all_right_star[1:]):
  num_kps_star.append(len(j))
```

```
all_feat_star_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_star):
  all_feat_star_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_brief[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_star_left_each.append(temp)
  all_feat_star_left.append(all_feat_star_left_each)
```

```
all_feat_star_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_star):
  all_feat_star_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_brief[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_star_right_each.append(temp)
  all_feat_star_right.append(all_feat_star_right_each)
```

```
del keypoints_all_left_star, keypoints_all_right_star, descriptors_all_left_brief, descriptors_all_right_brief
```

```
import pickle
Fdb = open('all_feat_star_left.dat', 'wb')
pickle.dump(all_feat_star_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_star_right.dat', 'wb')
pickle.dump(all_feat_star_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_star_left, all_feat_star_right
```

BRISK + FREAK

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:04<00:00,  1.45it/s]
     100%|██████████| 6/6 [00:03<00:00,  1.50it/s]
```

```
for j in tqdm(keypoints_all_left_freak + keypoints_all_right_freak[1:]):
  num_kps_freak.append(len(j))
```

```
all_feat_freak_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_freak):
  all_feat_freak_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_freak[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_freak_left_each.append(temp)
  all_feat_freak_left.append(all_feat_freak_left_each)
```

```
all_feat_freak_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_freak):
  all_feat_freak_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_freak[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_freak_right_each.append(temp)
  all_feat_freak_right.append(all_feat_freak_right_each)
```

```
del keypoints_all_left_freak, keypoints_all_right_freak, descriptors_all_left_freak, descriptors_all_right_freak
```

```
import pickle
Fdb = open('all_feat_freak_left.dat', 'wb')
pickle.dump(all_feat_freak_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_freak_right.dat', 'wb')
pickle.dump(all_feat_freak_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_freak_left, all_feat_freak_right
```

MSER + SIFT

```
start = timer()

mser = cv2.MSER_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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
100%|██████████| 6/6 [00:20<00:00,  3.34s/it]
100%|██████████| 6/6 [00:17<00:00,  2.98s/it]
```

```
for j in tqdm(keypoints_all_left_mser + keypoints_all_right_mser[1:]):
  num_kps_mser.append(len(j))
```

```
all_feat_mser_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_mser):
  all_feat_mser_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_mser[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_mser_left_each.append(temp)
  all_feat_mser_left.append(all_feat_mser_left_each)
```

```
all_feat_mser_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_mser):
  all_feat_mser_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_mser[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_mser_right_each.append(temp)
  all_feat_mser_right.append(all_feat_mser_right_each)
```

```
del keypoints_all_left_mser, keypoints_all_right_mser, descriptors_all_left_mser, descriptors_all_right_mser
```

```
import pickle
Fdb = open('all_feat_mser_left.dat', 'wb')
pickle.dump(all_feat_mser_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_mser_right.dat', 'wb')
pickle.dump(all_feat_mser_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_mser_left, all_feat_mser_right
```

AGAST + SIFT

```
start = timer()

agast = cv2.AgastFeatureDetector_create(threshold = 40)
sift = cv2.xfeatures2d.SIFT_create()

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

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

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  kpt = agast.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, 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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:08<00:00,  1.39s/it]
     100%|██████████| 6/6 [00:07<00:00,  1.25s/it]
```

```
for j in tqdm(keypoints_all_left_agast + keypoints_all_right_agast[1:]):
  num_kps_agast.append(len(j))
```

```
all_feat_agast_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_agast):
  all_feat_agast_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_agast[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_agast_left_each.append(temp)
  all_feat_agast_left.append(all_feat_agast_left_each)
```

```
all_feat_agast_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_agast):
  all_feat_agast_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_agast[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_agast_right_each.append(temp)
  all_feat_agast_right.append(all_feat_agast_right_each)
```

```
del keypoints_all_left_agast, keypoints_all_right_agast, descriptors_all_left_agast, descriptors_all_right_agast
```

```
import pickle
Fdb = open('all_feat_agast_left.dat', 'wb')
pickle.dump(all_feat_agast_left,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_agast_left
```

```
import pickle
Fdb = open('all_feat_agast_right.dat', 'wb')
pickle.dump(all_feat_agast_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_agast_right
```

FAST + SIFT

```
start = timer()


fast = cv2.FastFeatureDetector_create(threshold=40)
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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
100%|██████████| 6/6 [00:07<00:00,  1.17s/it]
100%|██████████| 6/6 [00:06<00:00,  1.09s/it]
```

```
for j in tqdm(keypoints_all_left_fast + keypoints_all_right_fast[1:]):
  num_kps_fast.append(len(j))
```

```
all_feat_fast_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_fast):
  all_feat_fast_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_fast[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_fast_left_each.append(temp)
  all_feat_fast_left.append(all_feat_fast_left_each)
```

```
all_feat_fast_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_fast):
  all_feat_fast_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_fast[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_fast_right_each.append(temp)
  all_feat_fast_right.append(all_feat_fast_right_each)
```

```
del keypoints_all_left_fast, keypoints_all_right_fast, descriptors_all_left_fast, descriptors_all_right_fast
```

```
import pickle
Fdb = open('all_feat_fast_left.dat', 'wb')
pickle.dump(all_feat_fast_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_fast_right.dat', 'wb')
pickle.dump(all_feat_fast_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_fast_left, all_feat_fast_right
```

GFTT + SIFT

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
    100%|██████████| 6/6 [00:01<00:00,  5.26it/s]
    100%|██████████| 6/6 [00:01<00:00,  5.33it/s]
```

```
for j in tqdm(keypoints_all_left_gftt + keypoints_all_right_gftt[1:]):
  num_kps_gftt.append(len(j))
```

```
all_feat_gftt_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_gftt):
  all_feat_gftt_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_gftt[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_gftt_left_each.append(temp)
  all_feat_gftt_left.append(all_feat_gftt_left_each)
```

```
all_feat_gftt_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_gftt):
  all_feat_gftt_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_gftt[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_gftt_right_each.append(temp)
  all_feat_gftt_right.append(all_feat_gftt_right_each)
```

```
del keypoints_all_left_gftt, keypoints_all_right_gftt, descriptors_all_left_gftt, descriptors_all_right_gftt
```

```
import pickle
Fdb = open('all_feat_gftt_left.dat', 'wb')
pickle.dump(all_feat_gftt_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_gftt_right.dat', 'wb')
pickle.dump(all_feat_gftt_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_gftt_left, all_feat_gftt_right
```

DAISY + SIFT

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
100%|██████████| 6/6 [00:05<00:00,  1.01it/s]
100%|██████████| 6/6 [00:05<00:00,  1.01it/s]
```

```
for j in tqdm(keypoints_all_left_daisy + keypoints_all_right_daisy[1:]):
  num_kps_daisy.append(len(j))
```

```
all_feat_daisy_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_daisy):
  all_feat_daisy_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_daisy[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_daisy_left_each.append(temp)
  all_feat_daisy_left.append(all_feat_daisy_left_each)
```

```
all_feat_daisy_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_daisy):
  all_feat_daisy_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_daisy[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_daisy_right_each.append(temp)
  all_feat_daisy_right.append(all_feat_daisy_right_each)
```

```
del keypoints_all_left_daisy, keypoints_all_right_daisy, descriptors_all_left_daisy, descriptors_all_right_daisy
```

```
import pickle
Fdb = open('all_feat_daisy_left.dat', 'wb')
pickle.dump(all_feat_daisy_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_daisy_right.dat', 'wb')
pickle.dump(all_feat_daisy_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_daisy_left, all_feat_daisy_right
```

SURF + SIFT

```
start = timer()

surf = cv2.xfeatures2d.SURF_create(upright=1)
sift = cv2.xfeatures2d.SIFT_create()

keypoints_all_left_surfsift = []
descriptors_all_left_surfsift = []
points_all_left_surfsift=[]

keypoints_all_right_surfsift = []
descriptors_all_right_surfsift = []
```

```
descriptors_all_right_surfsift=[]
points_all_right_surfsift=[]

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  kpt = surf.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_left_surfsift.append(kpt)
  descriptors_all_left_surfsift.append(descrip)
  #points_all_left_surfsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  kpt = surf.detect(imgs,None)
  kpt,descrip =  sift.compute(imgs, kpt)
  keypoints_all_right_surfsift.append(kpt)
  descriptors_all_right_surfsift.append(descrip)
  #points_all_right_surfsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:56<00:00,  9.35s/it]
     100%|██████████| 6/6 [00:56<00:00,  9.48s/it]
```

```
for j in tqdm(keypoints_all_left_surfsift + keypoints_all_right_surfsift[1:]):
  num_kps_surfsift.append(len(j))
```

```
all_feat_surfsift_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_surfsift):
  all_feat_surfsift_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_surfsift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_surfsift_left_each.append(temp)
  all_feat_surfsift_left.append(all_feat_surfsift_left_each)
```

```
all_feat_surfsift_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_surfsift):
  all_feat_surfsift_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_surfsift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_surfsift_right_each.append(temp)
  all_feat_surfsift_right.append(all_feat_surfsift_right_each)
```

```
del keypoints_all_left_surfsift, keypoints_all_right_surfsift, descriptors_all_left_surfsift, descriptors_all_right_surfsift
```

```
import pickle
Fdb = open('all_feat_surfsift_left.dat', 'wb')
pickle.dump(all_feat_surfsift_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_surfsift_right.dat', 'wb')
pickle.dump(all_feat_surfsift_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_surfsift_left, all_feat_surfsift_right
```

SIFT

```
print(len(left_files_path))
```

```
     6
```

```
print(len(right_files_path))
```

```
     6
```

```
# H5 file w/o compression
#t0=time.time()
#f=h5.File('drive/MyDrive/all_images_bgr_sift.h5','r')
#print('HDF5  w/o comp.: data shape =',len(f['data'][0]),time.time()-t0,'[s]')
#f.close()
```

```
#del f
```

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:08<00:00,  1.38s/it]
     100%|██████████| 6/6 [00:08<00:00,  1.38s/it]
```

```
for j in tqdm(keypoints_all_left_sift + keypoints_all_right_sift[1:]):
  num_kps_sift.append(len(j))
```

```
all_feat_sift_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_sift):
  all_feat_sift_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_sift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_sift_left_each.append(temp)
  all_feat_sift_left.append(all_feat_sift_left_each)
```

```
all_feat_sift_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_sift):
  all_feat_sift_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_sift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_sift_right_each.append(temp)
  all_feat_sift_right.append(all_feat_sift_right_each)
```

```
del keypoints_all_left_sift, keypoints_all_right_sift, descriptors_all_left_sift, descriptors_all_right_sift
```

```
import pickle
Fdb = open('all_feat_sift_left.dat', 'wb')
pickle.dump(all_feat_sift_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_sift_right.dat', 'wb')
pickle.dump(all_feat_sift_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_sift_left, all_feat_sift_right
```

```
#del keypoints_all_right_sift, keypoints_all_left_sift, descriptors_all_right_sift, descriptors_all_left_sift, points_all_right_sift, points_all_left_sift
```

SURF

```
start = timer()

surf  = cv2.xfeatures2d.SURF_create(upright=1)
keypoints_all_left_surf = []
descriptors_all_left_surf = []
points_all_left_surf=[]

keypoints_all_right_surf = []
descriptors_all_right_surf = []
points_all_right_surf=[]

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  kpt = surf.detect(imgs,None)
  kpt,descrip =  surf.compute(imgs, kpt)
  keypoints_all_left_surf.append(kpt)
  descriptors_all_left_surf.append(descrip)
  #points_all_left_surf.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

for cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  kpt = surf.detect(imgs,None)
  kpt,descrip =  surf.compute(imgs, kpt)
  keypoints_all_right_surf.append(kpt)
  descriptors_all_right_surf.append(descrip)
  #points_all_right_surf.append(np.asarray([[p.pt[0], p.pt[1]] for p in kpt]))

end = timer()

time_all.append(end-start)
```

```
    100%|██████████| 6/6 [00:06<00:00,  1.02s/it]
    100%|██████████| 6/6 [00:06<00:00,  1.03s/it]
```

```
for j in tqdm(keypoints_all_left_surf + keypoints_all_right_surf[1:]):
  num_kps_surf.append(len(j))
```

```
all_feat_surf_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_surf):
  all_feat_surf_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_surf[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_surf_left_each.append(temp)
  all_feat_surf_left.append(all_feat_surf_left_each)
```

```
all_feat_surf_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_surf):
  all_feat_surf_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_surf[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_surf_right_each.append(temp)
  all_feat_surf_right.append(all_feat_surf_right_each)
```

```
del keypoints_all_left_surf, keypoints_all_right_surf, descriptors_all_left_surf, descriptors_all_right_surf
```

```
import pickle
Fdb = open('all_feat_surf_left.dat', 'wb')
pickle.dump(all_feat_surf_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_surf_right.dat', 'wb')
pickle.dump(all_feat_surf_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_surf_left, all_feat_surf_right
```

ROOTSIFT

```
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)
```

```
start = timer()

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 cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt]
  f.close()
  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 cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  imgs = f['data'][cnt+len(left_files_path)]
  f.close()
  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]))

end = timer()

time_all.append(end-start)
```

```
     100%|██████████| 6/6 [00:08<00:00,  1.41s/it]
     100%|██████████| 6/6 [00:08<00:00,  1.39s/it]
```

```
for j in tqdm(keypoints_all_left_rootsift + keypoints_all_right_rootsift[1:]):
  num_kps_rootsift.append(len(j))
```

```
all_feat_rootsift_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_rootsift):
  all_feat_rootsift_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_rootsift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_rootsift_left_each.append(temp)
  all_feat_rootsift_left.append(all_feat_rootsift_left_each)
```

```
all_feat_rootsift_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_rootsift):
  all_feat_rootsift_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_rootsift[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_rootsift_right_each.append(temp)
  all_feat_rootsift_right.append(all_feat_rootsift_right_each)
  all_feat_rootsift_right.append(all_feat_rootsift_right_each)
```

```
del keypoints_all_left_rootsift, keypoints_all_right_rootsift, descriptors_all_left_rootsift, descriptors_all_right_rootsift
```

```
import pickle
Fdb = open('all_feat_rootsift_left.dat', 'wb')
pickle.dump(all_feat_rootsift_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_rootsift_right.dat', 'wb')
pickle.dump(all_feat_rootsift_right,Fdb,-1)
Fdb.close()
```

```
del Fdb, all_feat_rootsift_left, all_feat_rootsift_right
```

SuperPoint

```
!git clone https://github.com/magicleap/SuperPointPretrainedNetwork.git
```

```
weights_path = 'SuperPointPretrainedNetwork/superpoint_v1.pth'

cuda = 'True'
```

```
def to_kpts(pts, size=1):
  return [cv2.KeyPoint(pt[0], pt[1], size) for pt in pts]
```

```
import numpy as np
import torch
import torch.nn as nn
import torch.nn.functional as F

torch.cuda.empty_cache()

class SuperPointNet(nn.Module):
    def __init__(self):
        super(SuperPointNet, self).__init__()
        self.relu = nn.ReLU(inplace=True)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        c1, c2, c3, c4, c5, d1 = 64, 64, 128, 128, 256, 256
        # Shared Encoder.
        self.conv1a = nn.Conv2d(1, c1, kernel_size=3, stride=1, padding=1)
        self.conv1b = nn.Conv2d(c1, c1, kernel_size=3, stride=1, padding=1)
        self.conv2a = nn.Conv2d(c1, c2, kernel_size=3, stride=1, padding=1)
        self.conv2b = nn.Conv2d(c2, c2, kernel_size=3, stride=1, padding=1)
        self.conv3a = nn.Conv2d(c2, c3, kernel_size=3, stride=1, padding=1)
        self.conv3b = nn.Conv2d(c3, c3, kernel_size=3, stride=1, padding=1)
        self.conv4a = nn.Conv2d(c3, c4, kernel_size=3, stride=1, padding=1)
        self.conv4b = nn.Conv2d(c4, c4, kernel_size=3, stride=1, padding=1)
        # Detector Head.
        self.convPa = nn.Conv2d(c4, c5, kernel_size=3, stride=1, padding=1)
        self.convPb = nn.Conv2d(c5, 65, kernel_size=1, stride=1, padding=0)
        # Descriptor Head.
        self.convDa = nn.Conv2d(c4, c5, kernel_size=3, stride=1, padding=1)
        self.convDb = nn.Conv2d(c5, d1, kernel_size=1, stride=1, padding=0)
    def forward(self, x):

        # Shared Encoder.
        x = self.relu(self.conv1a(x))
        x = self.relu(self.conv1b(x))
        x = self.pool(x)
        x = self.relu(self.conv2a(x))
        x = self.relu(self.conv2b(x))
        x = self.pool(x)
        x = self.relu(self.conv3a(x))
        x = self.relu(self.conv3b(x))
        x = self.pool(x)
        x = self.relu(self.conv4a(x))
        x = self.relu(self.conv4b(x))
        # Detector Head.
        cPa = self.relu(self.convPa(x))
        semi = self.convPb(cPa)
        # Descriptor Head.
        cDa = self.relu(self.convDa(x))
        desc = self.convDb(cDa)
        dn = torch.norm(desc, p=2, dim=1) # Compute the norm.
        desc = desc.div(torch.unsqueeze(dn, 1)) # Divide by norm to normalize.
        return semi, desc


class SuperPointFrontend(object):
    def __init__(self, weights_path, nms_dist, conf_thresh, nn_thresh,cuda=True):
        self.name = 'SuperPoint'
        self.cuda = cuda
        self.nms_dist = nms_dist
        self.conf_thresh = conf_thresh
        self.nn_thresh = nn_thresh # L2 descriptor distance for good match.
        self.cell = 8 # Size of each output cell. Keep this fixed.
        self.border_remove = 4 # Remove points this close to the border.

        # Load the network in inference mode.
        self.net = SuperPointNet()
        if cuda:
          # Train on GPU, deploy on GPU.
            self.net.load_state_dict(torch.load(weights_path))
            self.net = self.net.cuda()
        else:
          # Train on GPU, deploy on CPU.
            self.net.load_state_dict(torch.load(weights_path, map_location=lambda storage, loc: storage))
        self.net.eval()

    def nms_fast(self, in_corners, H, W, dist_thresh):

        grid = np.zeros((H, W)).astype(int) # Track NMS data.
        inds = np.zeros((H, W)).astype(int) # Store indices of points.
        # Sort by confidence and round to nearest int.
        inds1 = np.argsort(-in_corners[2,:])
        corners = in_corners[:,inds1]
        rcorners = corners[:2,:].round().astype(int) # Rounded corners.
        # Check for edge case of 0 or 1 corners.
        if rcorners.shape[1] == 0:
            return np.zeros((3,0)).astype(int), np.zeros(0).astype(int)
        if rcorners.shape[1] == 1:
            out = np.vstack((rcorners, in_corners[2])).reshape(3,1)
            return out, np.zeros((1)).astype(int)
        # Initialize the grid.
        for i, rc in enumerate(rcorners.T):
            grid[rcorners[1,i], rcorners[0,i]] = 1
            inds[rcorners[1,i], rcorners[0,i]] = i
        # Pad the border of the grid, so that we can NMS points near the border.
        pad = dist_thresh
        grid = np.pad(grid, ((pad,pad), (pad,pad)), mode='constant')
        # Iterate through points, highest to lowest conf, suppress neighborhood.
        count = 0
        for i, rc in enumerate(rcorners.T):
          # Account for top and left padding.
            pt = (rc[0]+pad, rc[1]+pad)
            if grid[pt[1], pt[0]] == 1: # If not yet suppressed.
                grid[pt[1]-pad:pt[1]+pad+1, pt[0]-pad:pt[0]+pad+1] = 0
                grid[pt[1], pt[0]] = -1
                count += 1
        # Get all surviving -1's and return sorted array of remaining corners.
        keepy, keepx = np.where(grid==-1)
        keepy, keepx = keepy - pad, keepx - pad
        inds_keep = inds[keepy, keepx]
        out = corners[:, inds_keep]
        values = out[-1, :]
        inds2 = np.argsort(-values)
        out = out[:, inds2]
        out_inds = inds1[inds_keep[inds2]]
        return out, out_inds

    def run(self, img):
        assert img.ndim == 2 #Image must be grayscale.
        assert img.dtype == np.float32 #Image must be float32.
        H, W = img.shape[0], img.shape[1]
        inp = img.copy()
        inp = (inp.reshape(1, H, W))
        inp = torch.from_numpy(inp)
        inp = torch.autograd.Variable(inp).view(1, 1, H, W)
        if self.cuda:
            inp = inp.cuda()
        # Forward pass of network.
        outs = self.net.forward(inp)
        semi, coarse_desc = outs[0], outs[1]
        # Convert pytorch -> numpy.
        semi = semi.data.cpu().numpy().squeeze()

        # --- Process points.
        dense = np.exp(semi) # Softmax.
        dense = dense / (np.sum(dense, axis=0)+.00001) # Should sum to 1.
        nodust = dense[:-1, :, :]
        # Reshape to get full resolution heatmap.
        Hc = int(H / self.cell)
        Wc = int(W / self.cell)
        nodust = np.transpose(nodust, [1, 2, 0])
        heatmap = np.reshape(nodust, [Hc, Wc, self.cell, self.cell])
        heatmap = np.transpose(heatmap, [0, 2, 1, 3])
        heatmap = np.reshape(heatmap, [Hc*self.cell, Wc*self.cell])
        prob_map = heatmap/np.sum(np.sum(heatmap))

        return heatmap, coarse_desc


    def key_pt_sampling(self, img, heat_map, coarse_desc, sampled):

        H, W = img.shape[0], img.shape[1]
        H, W = img.shape[0], img.shape[1]

        xs, ys = np.where(heat_map >= self.conf_thresh) # Confidence threshold.
        if len(xs) == 0:
            return np.zeros((3, 0)), None, None
        print("number of pts selected :", len(xs))


        pts = np.zeros((3, len(xs))) # Populate point data sized 3xN.
        pts[0, :] = ys
        pts[1, :] = xs
        pts[2, :] = heat_map[xs, ys]
        pts, _ = self.nms_fast(pts, H, W, dist_thresh=self.nms_dist) # Apply NMS.
        inds = np.argsort(pts[2,:])
        pts = pts[:,inds[::-1]] # Sort by confidence.
        bord = self.border_remove
        toremoveW = np.logical_or(pts[0, :] < bord, pts[0, :] >= (W-bord))
        toremoveH = np.logical_or(pts[1, :] < bord, pts[1, :] >= (H-bord))
        toremove = np.logical_or(toremoveW, toremoveH)
        pts = pts[:, ~toremove]
        pts = pts[:,0:sampled] #we take 2000 keypoints with highest probability from heatmap for our benchmark

        # --- Process descriptor.
        D = coarse_desc.shape[1]
        if pts.shape[1] == 0:
            desc = np.zeros((D, 0))
        else:
          # Interpolate into descriptor map using 2D point locations.
            samp_pts = torch.from_numpy(pts[:2, :].copy())
            samp_pts[0, :] = (samp_pts[0, :] / (float(W)/2.)) - 1.
            samp_pts[1, :] = (samp_pts[1, :] / (float(H)/2.)) - 1.
            samp_pts = samp_pts.transpose(0, 1).contiguous()
            samp_pts = samp_pts.view(1, 1, -1, 2)
            samp_pts = samp_pts.float()
            if self.cuda:
                samp_pts = samp_pts.cuda()
            desc = nn.functional.grid_sample(coarse_desc, samp_pts)
            desc = desc.data.cpu().numpy().reshape(D, -1)
            desc /= np.linalg.norm(desc, axis=0)[np.newaxis, :]


        return pts, desc
```

```
print('Loading pre-trained network.')
# This class runs the SuperPoint network and processes its outputs.
fe = SuperPointFrontend(weights_path=weights_path,nms_dist = 3,conf_thresh = 0.01,nn_thresh=0.5)
print('Successfully loaded pre-trained network.')
```

```
keypoints_all_left_superpoint = []
descriptors_all_left_superpoint = []
points_all_left_superpoint=[]

keypoints_all_right_superpoint = []
descriptors_all_right_superpoint = []
points_all_right_superpoint=[]

tqdm = partial(tqdm, position=0, leave=True)

for cnt in tqdm(range(len(left_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  lfpth = f['data'][cnt]
  lfpth = f['data'][cnt]
  f.close()
  heatmap1, coarse_desc1 = fe.run(lfpth)
  pts_1, desc_1 = fe.key_pt_sampling(lfpth, heatmap1, coarse_desc1, 80000) #Getting keypoints and descriptors for 1st image

  keypoints_all_left_superpoint.append(to_kpts(pts_1.T))
  descriptors_all_left_superpoint.append(desc_1.T)
  #points_all_left_superpoint.append(pts_1.T)


for cnt in tqdm(range(len(right_files_path))):
  f=h5.File('drive/MyDrive/all_images_bgr_sift_40.h5','r')
  rfpth = f['data'][cnt]
  f.close()
  heatmap1, coarse_desc1 = fe.run(rfpth)
  pts_1, desc_1 = fe.key_pt_sampling(rfpth, heatmap1, coarse_desc1, 80000) #Getting keypoints and descriptors for 1st image

  keypoints_all_right_superpoint.append(to_kpts(pts_1.T))
  descriptors_all_right_superpoint.append(desc_1.T)
  #points_all_right_superpoint.append(pts_1.T)
```

```
for j in tqdm(keypoints_all_left_superpoint + keypoints_all_right_superpoint[1:]):
  num_kps_superpoint.append(len(j))
```

```
all_feat_superpoint_left = []
for cnt,kpt_all in enumerate(keypoints_all_left_superpoint):
  all_feat_superpoint_left_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_left_superpoint[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_superpoint_left_each.append(temp)
  all_feat_superpoint_left.append(all_feat_superpoint_left_each)
```

```
all_feat_superpoint_right = []
for cnt,kpt_all in enumerate(keypoints_all_right_superpoint):
  all_feat_superpoint_right_each = []
  for cnt_each, kpt in enumerate(kpt_all):
    desc = descriptors_all_right_superpoint[cnt][cnt_each]
    temp = (kpt.pt, kpt.size, kpt.angle, kpt.response, kpt.octave,
        kpt.class_id, desc)
    all_feat_superpoint_right_each.append(temp)
  all_feat_superpoint_right.append(all_feat_superpoint_right_each)
```

```
del keypoints_all_left_superpoint, keypoints_all_right_superpoint, descriptors_all_left_superpoint, descriptors_all_right_superpoint
```

```
import pickle
Fdb = open('all_feat_superpoint_left.dat', 'wb')
pickle.dump(all_feat_superpoint_left,Fdb,-1)
Fdb.close()
```

```
import pickle
Fdb = open('all_feat_superpoint_right.dat', 'wb')
pickle.dump(all_feat_superpoint_right,Fdb,-1)
Fdb.close()
Fdb.close()
```

```
del Fdb, all_feat_superpoint_left, all_feat_superpoint_right
```

Total Matches,Robust Matches and Homography Computation

```
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, maxIters=3000)
    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=0.75,thresh=4,use_lowe=True,disp=False,no_ransac=False,binary=False):
  lff1 = descripts[0]
  lff = descripts[1]

  if use_lowe==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()
    if binary==True:
      bf = cv2.BFMatcher(cv2.NORM_HAMMING, crossCheck=True)

    else:
      bf = cv2.BFMatcher(cv2.NORM_L2, crossCheck=True)
      lff1 = np.float32(descripts[0])
      lff = np.float32(descripts[1])


    #matches_lf1_lf = flann.knnMatch(lff1, lff, k=2)
    matches_4 = bf.knnMatch(lff1, lff,k=2)
    matches_lf1_lf = []


    print("\nNumber of matches",len(matches_4))
    '''
    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))
  else:
    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)
    if binary==True:
      bf = cv2.BFMatcher(cv2.NORM_HAMMING, crossCheck=True)
      lff1 = np.float32(descripts[0])
      lff = np.float32(descripts[1])
    else:
      bf = cv2.BFMatcher(cv2.NORM_L2, crossCheck=True)
      lff1 = np.float32(descripts[0])
      lff = np.float32(descripts[1])


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

  if no_ransac==True:
    Hn,inliers = compute_homography_fast_other(imm1_pts,imm2_pts)
  else:
    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)<25:
    matches_4 = []
    ratio = 0.85
    # 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(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,flags=2)
    displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')


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

```
def get_Hmatrix_rfnet(imgs,pts,descripts,disp=True):

  des1 = descripts[0]
  des2 = descripts[1]

  kp1 = pts[0]
  kp2 = pts[1]


  predict_label, nn_kp2 = nearest_neighbor_distance_ratio_match(des1, des2, kp2, 0.7)
  idx = predict_label.nonzero().view(-1)
  mkp1 = kp1.index_select(dim=0, index=idx.long())  # predict match keypoints in I1
  mkp2 = nn_kp2.index_select(dim=0, index=idx.long())  # predict match keypoints in I2
  #img1, img2 = reverse_img(img1), reverse_img(img2)
  keypoints1 = list(map(to_cv2_kp, mkp1))
  keypoints2 = list(map(to_cv2_kp, mkp2))
  DMatch = list(map(to_cv2_dmatch, np.arange(0, len(keypoints1))))

  imm1_pts=np.empty((len(DMatch),2))
  imm2_pts=np.empty((len(DMatch),2))
  for i in range(0,len(DMatch)):
    m = DMatch[i]
    (a_x, a_y) = keypoints1[m.queryIdx].pt
    (b_x, b_y) = keypoints2[m.trainIdx].pt
    imm1_pts[i]=(a_x, a_y)
    imm2_pts[i]=(b_x, b_y)
  H=compute_Homography_fast(imm1_pts,imm2_pts)


  if disp==True:
    dispimg1 = cv2.drawMatches(imgs[0], keypoints1, imgs[1], keypoints2, DMatch, None)
    displayplot(dispimg1,'Robust Matching between Reference Image and Right Image ')


  return H/H[2,2]
```

```
import pickle
Fdb = open('all_feat_brisk_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

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

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                                _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_brisk.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_brisk.append(keypoints_each)
  descriptors_all_left_brisk.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_brisk_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

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

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_brisk.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_brisk.append(keypoints_each)
  descriptors_all_right_brisk.append(descrip_each)
```

```
H_left_brisk = []
H_right_brisk = []

num_matches_brisk = []
num_good_matches_brisk = []

images_left_bgr = []
images_right_bgr = []
for j in tqdm(range(len(left_files_path))):
  if j==len(left_files_path)-1:
    break

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_brisk[j:j+2][::-1],points_all_left_brisk[j:j+2][::-1],descriptors_all_left_brisk[j:j+2][::-1],0.7,3,use_lowe=True,binary=True)
  H_left_brisk.append(H_a)
  num_matches_brisk.append(matches)
  num_good_matches_brisk.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_brisk[j:j+2][::-1],points_all_right_brisk[j:j+2][::-1],descriptors_all_right_brisk[j:j+2][::-1],0.7,3,use_lowe=True,binary=True)
  H_right_brisk.append(H_a)
  num_matches_brisk.append(matches)
  num_good_matches_brisk.append(gd_matches)
```

```
 17%|██        | 1/6 [00:01<00:07,  1.50s/it]
Number of matches 29156
Number of matches After Lowe's Ratio 890
Number of Robust matches 521


 33%|███       | 2/6 [00:03<00:06,  1.60s/it]
Number of matches 32829
Number of matches After Lowe's Ratio 1353
Number of Robust matches 655


 50%|█████     | 3/6 [00:05<00:05,  1.76s/it]
Number of matches 33000
Number of matches After Lowe's Ratio 791
Number of Robust matches 307


 67%|██████▋   | 4/6 [00:07<00:03,  1.87s/it]
Number of matches 35928
Number of matches After Lowe's Ratio 1317
Number of Robust matches 447


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 25311
Number of matches After Lowe's Ratio 270
Number of Robust matches 120
```

```
 17%|█▋        | 1/6 [00:01<00:09,  1.81s/it]
Number of matches 32773
Number of matches After Lowe's Ratio 1060
Number of Robust matches 701


 33%|███▎      | 2/6 [00:03<00:07,  1.81s/it]
Number of matches 27675
Number of matches After Lowe's Ratio 785
Number of Robust matches 568


 50%|█████     | 3/6 [00:05<00:05,  1.73s/it]
Number of matches 27359
Number of matches After Lowe's Ratio 1189
Number of Robust matches 786


 67%|██████▋   | 4/6 [00:06<00:03,  1.72s/it]
Number of matches 27879
Number of matches After Lowe's Ratio 782
Number of Robust matches 618


 83%|████████▎ | 5/6 [00:08<00:01,  1.69s/it]
Number of matches 31024
Number of matches After Lowe's Ratio 848
Number of Robust matches 597
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_brisk_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_brisk)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_brisk_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.02454400062561035 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_brisk_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_brisk)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_brisk_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.004817485809326172 [s] ... size 0.002408 MB
```

```
del H_left_brisk, H_right_brisk,keypoints_all_left_brisk, keypoints_all_right_brisk, descriptors_all_left_brisk, descriptors_all_right_brisk, points_all_left_brisk, points_all_right_brisk
```

```
import pickle
Fdb = open('all_feat_sift_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_sift = []
descriptors_all_left_sift = []



for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_sift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_sift.append(keypoints_each)
  descriptors_all_left_sift.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_sift_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_sift = []
descriptors_all_right_sift = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_sift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_sift.append(keypoints_each)
  descriptors_all_right_sift.append(descrip_each)
```

```
H_left_sift = []
H_right_sift = []

num_matches_sift = []
num_good_matches_sift = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_sift[j:j+2][::-1],points_all_left_sift[j:j+2][::-1],descriptors_all_left_sift[j:j+2][::-1],0.5)
  H_left_sift.append(H_a)
  num_matches_sift.append(matches)
  num_good_matches_sift.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_sift[j:j+2][::-1],points_all_right_sift[j:j+2][::-1],descriptors_all_right_sift[j:j+2][::-1],0.5)
  H_right_sift.append(H_a)
  num_matches_sift.append(matches)
  num_good_matches_sift.append(gd_matches)
```

```
 17%|██        | 1/6 [00:02<00:14,  2.80s/it]
Number of matches 30579
Number of matches After Lowe's Ratio 1440
Number of Robust matches 965


 33%|███▎      | 2/6 [00:05<00:11,  2.88s/it]
Number of matches 29556
Number of matches After Lowe's Ratio 2239
Number of Robust matches 1166


 50%|█████     | 3/6 [00:08<00:08,  2.92s/it]
Number of matches 30860
Number of matches After Lowe's Ratio 1152
Number of Robust matches 624


 67%|██████▋   | 4/6 [00:11<00:05,  2.96s/it]
Number of matches 30396
Number of matches After Lowe's Ratio 1934
Number of Robust matches 965


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 26655
Number of matches After Lowe's Ratio 446
Number of Robust matches 228


 17%|█▋        | 1/6 [00:03<00:16,  3.25s/it]
Number of matches 30376
Number of matches After Lowe's Ratio 1644
Number of Robust matches 1278


 33%|███▎      | 2/6 [00:06<00:12,  3.15s/it]
Number of matches 30770
Number of matches After Lowe's Ratio 1287
Number of Robust matches 946


 50%|█████     | 3/6 [00:09<00:09,  3.09s/it]
Number of matches 30356
Number of matches After Lowe's Ratio 1943
Number of Robust matches 1601


 67%|██████▋   | 4/6 [00:12<00:06,  3.04s/it]
Number of matches 28897
Number of matches After Lowe's Ratio 1377
Number of Robust matches 1136


 83%|████████▎ | 5/6 [00:14<00:02,  2.92s/it]
Number of matches 27133
Number of matches After Lowe's Ratio 1413
Number of Robust matches 1184
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_sift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_sift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_sift_40.h5')/1.e6,'MB')
```

```
    HDF5  w/o comp.: 0.004568815231323242 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_sift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_sift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_sift_40.h5')/1.e6,'MB')
```

```
    HDF5  w/o comp.: 0.011300802230834961 [s] ... size 0.002408 MB
```

```
del H_left_sift, H_right_sift,keypoints_all_left_sift, keypoints_all_right_sift, descriptors_all_left_sift, descriptors_all_right_sift, points_all_left_sift, points_all_right_sift
```

```
import pickle
Fdb = open('all_feat_fast_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_fast = []
descriptors_all_left_fast = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_fast.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_fast.append(keypoints_each)
  descriptors_all_left_fast.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_fast_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_fast = []
descriptors_all_right_fast = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_fast.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_fast.append(keypoints_each)
  descriptors_all_right_fast.append(descrip_each)
```

```
H_left_fast = []
H_right_fast = []
H_right_fast = []

num_matches_fast = []
num_good_matches_fast = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_fast[j:j+2][::-1],points_all_left_fast[j:j+2][::-1],descriptors_all_left_fast[j:j+2][::-1],0.7,6)
  H_left_fast.append(H_a)
  num_matches_fast.append(matches)
  num_good_matches_fast.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_fast[j:j+2][::-1],points_all_right_fast[j:j+2][::-1],descriptors_all_right_fast[j:j+2][::-1],0.7,6)
  H_right_fast.append(H_a)
  num_matches_fast.append(matches)
  num_good_matches_fast.append(gd_matches)
```

```
 17%|█▋        | 1/6 [00:03<00:17,  3.57s/it]
Number of matches 37205
Number of matches After Lowe's Ratio 3137
Number of Robust matches 1989


 33%|███▎      | 2/6 [00:08<00:15,  3.94s/it]
Number of matches 40072
Number of matches After Lowe's Ratio 2677
Number of Robust matches 1674


 50%|█████     | 3/6 [00:12<00:12,  4.11s/it]
Number of matches 40931
Number of matches After Lowe's Ratio 1550
Number of Robust matches 812


 67%|██████▋   | 4/6 [00:18<00:08,  4.47s/it]
Number of matches 43570
Number of matches After Lowe's Ratio 3421
Number of Robust matches 1971


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 33997
Number of matches After Lowe's Ratio 198
Number of Robust matches 114


 17%|█▋        | 1/6 [00:04<00:20,  4.12s/it]
Number of matches 37654
Number of matches After Lowe's Ratio 1407
Number of Robust matches 1165


 33%|███▎      | 2/6 [00:08<00:16,  4.22s/it]
Number of matches 36445
Number of matches After Lowe's Ratio 1812
Number of Robust matches 1518
Number of matches 34581
Number of matches After Lowe's Ratio 7435
 50%|█████     | 3/6 [00:12<00:12,  4.22s/it]Number of Robust matches 6464


 67%|███████   | 4/6 [00:16<00:08,  4.07s/it]
Number of matches 35872
Number of matches After Lowe's Ratio 4924
Number of Robust matches 4445


 83%|████████▎ | 5/6 [00:20<00:04,  4.11s/it]
Number of matches 36947
Number of matches After Lowe's Ratio 4540
Number of Robust matches 4126
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_fast_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_fast)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_fast_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.004185914993286133 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_fast_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_fast)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_fast_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.006817340850830078 [s] ... size 0.002408 MB
```

```
del H_left_fast, H_right_fast,keypoints_all_left_fast, keypoints_all_right_fast, descriptors_all_left_fast, descriptors_all_right_fast, points_all_left_fast, points_all_right_fast
```

```
import pickle
Fdb = open('all_feat_orb_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_orb = []
descriptors_all_left_orb = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_orb.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_orb.append(keypoints_each)
  keypoints_all_left_orb.append(keypoints_each)
  descriptors_all_left_orb.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_orb_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_orb = []
descriptors_all_right_orb = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                                _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_orb.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_orb.append(keypoints_each)
  descriptors_all_right_orb.append(descrip_each)
```

```
H_left_orb = []
H_right_orb = []

num_matches_orb = []
num_good_matches_orb = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_orb[j:j+2][::-1],points_all_left_orb[j:j+2][::-1],descriptors_all_left_orb[j:j+2][::-1],0.7)
  H_left_orb.append(H_a)
  num_matches_orb.append(matches)
  num_good_matches_orb.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_orb[j:j+2][::-1],points_all_right_orb[j:j+2][::-1],descriptors_all_right_orb[j:j+2][::-1],0.7)
  H_right_orb.append(H_a)
  num_matches_orb.append(matches)
  num_good_matches_orb.append(gd_matches)
```

```
 17%|██        | 1/6 [00:00<00:03,  1.39it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 398
Number of Robust matches 202


 33%|███       | 2/6 [00:01<00:02,  1.49it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 427
Number of Robust matches 203


 50%|█████     | 3/6 [00:01<00:01,  1.56it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 275
Number of Robust matches 93


 67%|██████▋   | 4/6 [00:02<00:01,  1.64it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 423
Number of Robust matches 159


 83%|████████▎ | 5/6 [00:02<00:00,  1.68it/s]
  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 154
Number of Robust matches 40


 17%|█▋        | 1/6 [00:00<00:03,  1.40it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 415
Number of Robust matches 307


 33%|███▎      | 2/6 [00:01<00:02,  1.51it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 360
Number of Robust matches 235


 50%|█████     | 3/6 [00:01<00:01,  1.61it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 558
Number of Robust matches 350


 67%|██████▋   | 4/6 [00:02<00:01,  1.67it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 331
Number of Robust matches 231


 83%|████████▎ | 5/6 [00:03<00:00,  1.58it/s]
Number of matches 20000
Number of matches After Lowe's Ratio 366
Number of Robust matches 213
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_orb_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_orb)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_orb_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.007872343063354492 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_orb_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_orb)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_orb_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0057904720306396484 [s] ... size 0.002408 MB
```

```
del H_left_orb, H_right_orb,keypoints_all_left_orb, keypoints_all_right_orb, descriptors_all_left_orb, descriptors_all_right_orb, points_all_left_orb, points_all_right_orb
```

```
import pickle
Fdb = open('all_feat_kaze_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_kaze = []
descriptors_all_left_kaze = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_kaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_kaze.append(keypoints_each)
  descriptors_all_left_kaze.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_kaze_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_kaze = []
descriptors_all_right_kaze = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_kaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_kaze.append(keypoints_each)
  descriptors_all_right_kaze.append(descrip_each)
```

```
H_left_kaze = []
H_right_kaze = []

num_matches_kaze = []
num_good_matches_kaze = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_kaze[j:j+2][::-1],points_all_left_kaze[j:j+2][::-1],descriptors_all_left_kaze[j:j+2][::-1])
  H_left_kaze.append(H_a)
  num_matches_kaze.append(matches)
  num_good_matches_kaze.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_kaze[j:j+2][::-1],points_all_right_kaze[j:j+2][::-1],descriptors_all_right_kaze[j:j+2][::-1])
  H_right_kaze.append(H_a)
  num_matches_kaze.append(matches)
  num_good_matches_kaze.append(gd_matches)
```

```
 17%|██        | 1/6 [00:00<00:04,  1.01it/s]
Number of matches 20754
Number of matches After Lowe's Ratio 4847
Number of Robust matches 2663


 33%|███       | 2/6 [00:02<00:04,  1.05s/it]
Number of matches 21466
Number of matches After Lowe's Ratio 6510
Number of Robust matches 3243



Number of matches 22210
Number of matches After Lowe's Ratio 4501
 50%|█████     | 3/6 [00:03<00:03,  1.11s/it]Number of Robust matches 1740


 67%|██████▋   | 4/6 [00:04<00:02,  1.14s/it]
Number of matches 22050
Number of matches After Lowe's Ratio 5923
Number of Robust matches 2109


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 19110
Number of matches After Lowe's Ratio 1831
Number of Robust matches 544


 17%|██        | 1/6 [00:01<00:05,  1.13s/it]
Number of matches 21286
Number of matches After Lowe's Ratio 5796
Number of Robust matches 3867


 33%|███       | 2/6 [00:02<00:04,  1.16s/it]
Number of matches 21133
Number of matches After Lowe's Ratio 5118
Number of Robust matches 3669


 50%|█████     | 3/6 [00:03<00:03,  1.14s/it]
Number of matches 20924
Number of matches After Lowe's Ratio 6901
Number of Robust matches 5278


 67%|██████▋   | 4/6 [00:04<00:02,  1.11s/it]
Number of matches 19699
Number of matches After Lowe's Ratio 5042
Number of Robust matches 3547



Number of matches 21574
Number of matches After Lowe's Ratio 4736
 83%|████████  | 5/6 [00:05<00:01,  1.14s/it]Number of Robust matches 3422
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_kaze_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_kaze)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_kaze_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.005415916442871094 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_kaze_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_kaze)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_kaze_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.005000114440917969 [s] ... size 0.002408 MB
```

```
del H_left_kaze, H_right_kaze,keypoints_all_left_kaze, keypoints_all_right_kaze, descriptors_all_left_kaze, descriptors_all_right_kaze, points_all_left_kaze, points_all_right_kaze
```

```
import pickle
Fdb = open('all_feat_akaze_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_akaze = []
descriptors_all_left_akaze = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_akaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_akaze.append(keypoints_each)
  descriptors_all_left_akaze.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_akaze_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_akaze = []
descriptors_all_right_akaze = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
```

```
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_akaze.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_akaze.append(keypoints_each)
  descriptors_all_right_akaze.append(descrip_each)
```

```
H_left_akaze = []
H_right_akaze = []

num_matches_akaze = []
num_good_matches_akaze = []

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

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

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_akaze[j:j+2][::-1],points_all_right_akaze[j:j+2][::-1],descriptors_all_right_akaze[j:j+2][::-1])
  H_right_akaze.append(H_a)
  num_matches_akaze.append(matches)
  num_good_matches_akaze.append(gd_matches)
```

```
 17%|█▋        | 1/6 [00:00<00:03,  1.29it/s]
Number of matches 18446
Number of matches After Lowe's Ratio 2216
Number of Robust matches 1205


 33%|███▎      | 2/6 [00:01<00:03,  1.27it/s]
Number of matches 19154
Number of matches After Lowe's Ratio 2725
Number of Robust matches 1481


 50%|█████     | 3/6 [00:02<00:02,  1.17it/s]
Number of matches 20674
Number of matches After Lowe's Ratio 1770
Number of Robust matches 720


 67%|██████▋   | 4/6 [00:03<00:01,  1.13it/s]
Number of matches 20317
Number of matches After Lowe's Ratio 2089
Number of Robust matches 797


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 17535
Number of matches After Lowe's Ratio 740
Number of Robust matches 206
```

```
 17%|█▌        | 1/6 [00:00<00:04,  1.16it/s]
Number of matches 18717
Number of matches After Lowe's Ratio 2338
Number of Robust matches 1598


 33%|███▎      | 2/6 [00:01<00:03,  1.18it/s]
Number of matches 18253
Number of matches After Lowe's Ratio 1909
Number of Robust matches 1257


 50%|█████     | 3/6 [00:02<00:02,  1.13it/s]
Number of matches 17759
Number of matches After Lowe's Ratio 2901
Number of Robust matches 2038


 67%|██████▋   | 4/6 [00:03<00:01,  1.20it/s]
Number of matches 16473
Number of matches After Lowe's Ratio 2137
Number of Robust matches 1610


 83%|████████▎ | 5/6 [00:04<00:00,  1.22it/s]
Number of matches 18293
Number of matches After Lowe's Ratio 2172
Number of Robust matches 1612
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_akaze_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_akaze)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_akaze_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.004241943359375 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_akaze_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_akaze)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_akaze_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.003307342529296875 [s] ... size 0.002408 MB
```

```
del H_left_akaze, H_right_akaze,keypoints_all_left_akaze, keypoints_all_right_akaze, descriptors_all_left_akaze, descriptors_all_right_akaze, points_all_left_akaze, points_all_right_akaze
```

```
import pickle
Fdb = open('all_feat_star_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_star = []
descriptors_all_left_brief = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_star.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_star.append(keypoints_each)
  descriptors_all_left_brief.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_star_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_star = []
descriptors_all_right_brief = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_star.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_star.append(keypoints_each)
  descriptors_all_right_brief.append(descrip_each)
```

```
H_left_brief = []
H_right_brief = []

num_matches_briefstar = []
num_good_matches_briefstar = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_star[j:j+2][::-1],points_all_left_star[j:j+2][::-1],descriptors_all_left_brief[j:j+2][::-1])
  H_left_brief.append(H_a)
  num_matches_briefstar.append(matches)
  num_good_matches_briefstar.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_star[j:j+2][::-1],points_all_right_star[j:j+2][::-1],descriptors_all_right_brief[j:j+2][::-1])
  H_right_brief.append(H_a)
  num_matches_briefstar.append(matches)
  num_good_matches_briefstar.append(gd_matches)
```

```
     33%|███       | 2/6 [00:00<00:01,  3.93it/s]
    Number of matches 6030
    Number of matches After Lowe's Ratio 656
    Number of Robust matches 211
```

```
Number of matches 6742
Number of matches After Lowe's Ratio 657
Number of Robust matches 207


 50%|█████     | 3/6 [00:00<00:00,  4.22it/s]
Number of matches 7144
Number of matches After Lowe's Ratio 649
Number of Robust matches 136



Number of matches 7263
Number of matches After Lowe's Ratio 802
 67%|██████▋   | 4/6 [00:00<00:00,  4.58it/s]Number of Robust matches 205



Number of matches 5783
Number of matches After Lowe's Ratio 321
Number of Robust matches 10


Number of matches After Lowe's Ratio New 687
 83%|████████▎ | 5/6 [00:01<00:00,  4.67it/s]
 17%|█▋        | 1/6 [00:00<00:00,  6.68it/s]Number of Robust matches New 13



Number of matches 6654
Number of matches After Lowe's Ratio 505
Number of Robust matches 155


 50%|█████     | 3/6 [00:00<00:00,  6.68it/s]
Number of matches 6684
Number of matches After Lowe's Ratio 582
Number of Robust matches 204



Number of matches 6699
Number of matches After Lowe's Ratio 1326
Number of Robust matches 810


 83%|████████▎ | 5/6 [00:00<00:00,  6.85it/s]
Number of matches 5955
Number of matches After Lowe's Ratio 897
Number of Robust matches 478
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_brief_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_brief)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_brief_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0059545040130615234 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_brief_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_brief)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_brief_40.h5')/1.e6,'MB')
```

```
     HDF5  w/o comp.: 0.0036389827728271484 [s] ... size 0.002408 MB
```

```
del H_left_brief, H_right_brief,keypoints_all_left_star, keypoints_all_right_star, descriptors_all_left_brief, descriptors_all_right_brief, points_all_left_star, points_all_right_star
```

```
import pickle
Fdb = open('all_feat_agast_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_agast = []
descriptors_all_left_agast = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_agast.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_agast.append(keypoints_each)
  descriptors_all_left_agast.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_agast_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_agast = []
descriptors_all_right_agast = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_agast.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_agast.append(keypoints_each)
  descriptors_all_right_agast.append(descrip_each)
```

```
H_left_agast = []
H_right_agast = []

num_matches_agast = []
```

```
num_good_matches_agast = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_agast[j:j+2][::-1],points_all_left_agast[j:j+2][::-1],descriptors_all_left_agast[j:j+2][::-1],0.7,6)
  H_left_agast.append(H_a)
  num_matches_agast.append(matches)
  num_good_matches_agast.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_agast[j:j+2][::-1],points_all_right_agast[j:j+2][::-1],descriptors_all_right_agast[j:j+2][::-1],0.7,6)
  H_right_agast.append(H_a)
  num_matches_agast.append(matches)
  num_good_matches_agast.append(gd_matches)
```

```
     17%|██        | 1/6 [00:04<00:22,  4.50s/it]
    Number of matches 44131
    Number of matches After Lowe's Ratio 2926
    Number of Robust matches 1791


     33%|███▎      | 2/6 [00:10<00:19,  4.92s/it]
    Number of matches 45681
    Number of matches After Lowe's Ratio 2415
    Number of Robust matches 1430


     50%|█████     | 3/6 [00:16<00:15,  5.16s/it]
    Number of matches 48199
    Number of matches After Lowe's Ratio 1438
    Number of Robust matches 831


     67%|██████▋   | 4/6 [00:22<00:11,  5.56s/it]
    Number of matches 51607
    Number of matches After Lowe's Ratio 3155
    Number of Robust matches 1973


      0%|          | 0/6 [00:00<?, ?it/s]
    Number of matches 38563
    Number of matches After Lowe's Ratio 217
    Number of Robust matches 116


     17%|██        | 1/6 [00:04<00:24,  4.87s/it]
    Number of matches 43952
    Number of matches After Lowe's Ratio 1284
    Number of Robust matches 881


     33%|███▎      | 2/6 [00:09<00:19,  4.87s/it]
    Number of matches 39882
    Number of matches After Lowe's Ratio 1749
    Number of Robust matches 1199


     50%|█████     | 3/6 [00:14<00:14,  4.87s/it]
    Number of matches 37550
    Number of matches After Lowe's Ratio 7202
    Number of Robust matches 5932
```

```
 67%|██████▋   | 4/6 [00:18<00:09,  4.69s/it]
Number of matches 39620
Number of matches After Lowe's Ratio 4927
Number of Robust matches 4370


 83%|████████▎ | 5/6 [00:23<00:04,  4.69s/it]
Number of matches 40937
Number of matches After Lowe's Ratio 4334
Number of Robust matches 3754
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_agast_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_agast)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_agast_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0057430267333984375 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_agast_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_agast)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_agast_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0032486915588378906 [s] ... size 0.002408 MB
```

```
del H_left_agast, H_right_agast,keypoints_all_left_agast, keypoints_all_right_agast, descriptors_all_left_agast, descriptors_all_right_agast, points_all_left_agast, points_all_right_agast
```

```
import pickle
Fdb = open('all_feat_daisy_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_daisy = []
descriptors_all_left_daisy = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                        _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_daisy.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_daisy.append(keypoints_each)
  descriptors_all_left_daisy.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_daisy_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_daisy = []
descriptors_all_right_daisy = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_daisy.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_daisy.append(keypoints_each)
  descriptors_all_right_daisy.append(descrip_each)
```

```
H_left_daisy = []
H_right_daisy = []

num_matches_daisy = []
num_good_matches_daisy = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_daisy[j:j+2][::-1],points_all_left_daisy[j:j+2][::-1],descriptors_all_left_daisy[j:j+2][::-1],0.7,6)
  H_left_daisy.append(H_a)
  num_matches_daisy.append(matches)
  num_good_matches_daisy.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_daisy[j:j+2][::-1],points_all_right_daisy[j:j+2][::-1],descriptors_all_right_daisy[j:j+2][::-1],0.7,6)
  H_right_daisy.append(H_a)
  num_matches_daisy.append(matches)
  num_good_matches_daisy.append(gd_matches)
```

```
 17%|██        | 1/6 [00:03<00:19,  3.92s/it]
Number of matches 30579
Number of matches After Lowe's Ratio 2666
Number of Robust matches 1631


 33%|███▎      | 2/6 [00:08<00:15,  4.00s/it]
Number of matches 29556
Number of matches After Lowe's Ratio 3750
Number of Robust matches 2446


 50%|█████     | 3/6 [00:11<00:11,  3.92s/it]
Number of matches 30860
Number of matches After Lowe's Ratio 1663
Number of Robust matches 984


 67%|██████▋   | 4/6 [00:16<00:08,  4.02s/it]
Number of matches 30396
Number of matches After Lowe's Ratio 3656
Number of Robust matches 2302


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 26655
Number of matches After Lowe's Ratio 555
Number of Robust matches 260


 17%|█▋        | 1/6 [00:04<00:20,  4.03s/it]
Number of matches 30376
Number of matches After Lowe's Ratio 2853
Number of Robust matches 2099


 33%|███▎      | 2/6 [00:08<00:16,  4.02s/it]
Number of matches 30770
Number of matches After Lowe's Ratio 2087
Number of Robust matches 1731


 50%|█████     | 3/6 [00:12<00:12,  4.07s/it]
Number of matches 30356
Number of matches After Lowe's Ratio 5426
Number of Robust matches 4494


 67%|██████▋   | 4/6 [00:15<00:07,  3.96s/it]
Number of matches 28897
Number of matches After Lowe's Ratio 3292
Number of Robust matches 2752


 83%|████████▎ | 5/6 [00:19<00:03,  3.88s/it]
Number of matches 27133
Number of matches After Lowe's Ratio 2840
Number of Robust matches 1727
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_daisy_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_daisy)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_daisy_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0037031173706054688 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_daisy_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_daisy)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_daisy_40.h5')/1.e6,'MB')
```

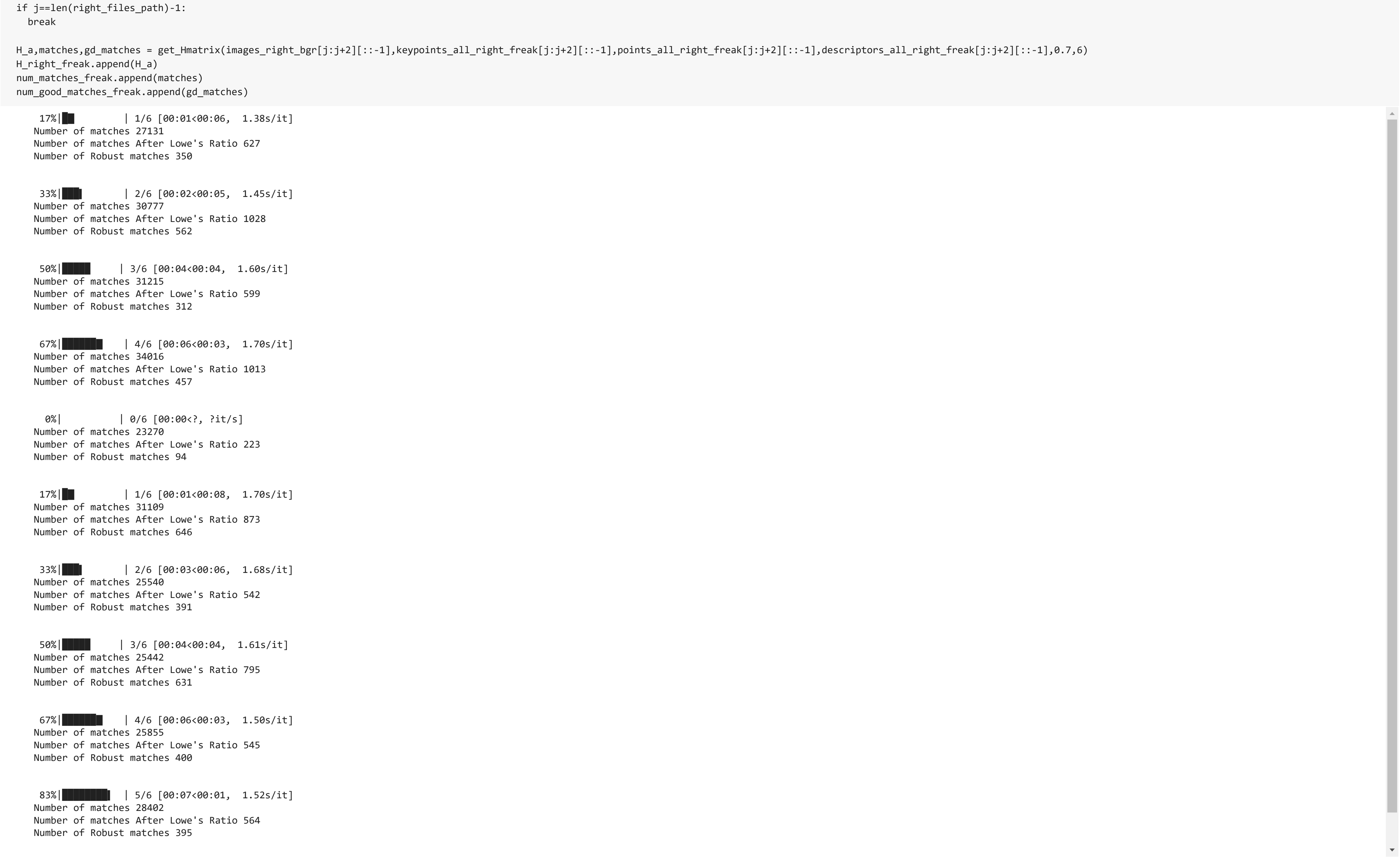
```
HDF5  w/o comp.: 0.005590200424194336 [s] ... size 0.002408 MB
```

```
del H_left_daisy, H_right_daisy,keypoints_all_left_daisy, keypoints_all_right_daisy, descriptors_all_left_daisy, descriptors_all_right_daisy, points_all_left_daisy, points_all_right_daisy
del H_left_daisy, H_right_daisy,keypoints_all_left_daisy, keypoints_all_right_daisy, descriptors_all_left_daisy, descriptors_all_right_daisy, points_all_left_daisy, points_all_right_daisy
```

```
import pickle
Fdb = open('all_feat_freak_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_freak = []
descriptors_all_left_freak = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_freak.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_freak.append(keypoints_each)
  descriptors_all_left_freak.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_freak_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_freak = []
descriptors_all_right_freak = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_freak.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_freak.append(keypoints_each)
  descriptors_all_right_freak.append(descrip_each)
```

```
H_left_freak = []
H_right_freak = []

num_matches_freak = []
num_good_matches_freak = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_freak[j:j+2][::-1],points_all_left_freak[j:j+2][::-1],descriptors_all_left_freak[j:j+2][::-1],0.7,6)
  H_left_freak.append(H_a)
  num_matches_freak.append(matches)
  num_good_matches_freak.append(gd_matches)

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



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

H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_freak[j:j+2][::-1],points_all_right_freak[j:j+2][::-1],descriptors_all_right_freak[j:j+2][::-1],0.7,6)
H_right_freak.append(H_a)
num_matches_freak.append(matches)
num_good_matches_freak.append(gd_matches)
```

```
 17%|██        | 1/6 [00:01<00:06,  1.38s/it]
Number of matches 27131
Number of matches After Lowe's Ratio 627
Number of Robust matches 350


 33%|███       | 2/6 [00:02<00:05,  1.45s/it]
Number of matches 30777
Number of matches After Lowe's Ratio 1028
Number of Robust matches 562


 50%|█████     | 3/6 [00:04<00:04,  1.60s/it]
Number of matches 31215
Number of matches After Lowe's Ratio 599
Number of Robust matches 312


 67%|██████▋   | 4/6 [00:06<00:03,  1.70s/it]
Number of matches 34016
Number of matches After Lowe's Ratio 1013
Number of Robust matches 457


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 23270
Number of matches After Lowe's Ratio 223
Number of Robust matches 94


 17%|██        | 1/6 [00:01<00:08,  1.70s/it]
Number of matches 31109
Number of matches After Lowe's Ratio 873
Number of Robust matches 646


 33%|███       | 2/6 [00:03<00:06,  1.68s/it]
Number of matches 25540
Number of matches After Lowe's Ratio 542
Number of Robust matches 391


 50%|█████     | 3/6 [00:04<00:04,  1.61s/it]
Number of matches 25442
Number of matches After Lowe's Ratio 795
Number of Robust matches 631


 67%|██████▋   | 4/6 [00:06<00:03,  1.50s/it]
Number of matches 25855
Number of matches After Lowe's Ratio 545
Number of Robust matches 400


 83%|████████▎ | 5/6 [00:07<00:01,  1.52s/it]
Number of matches 28402
Number of matches After Lowe's Ratio 564
Number of Robust matches 395
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_freak_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_freak)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_freak_40.h5')/1.e6,'MB')
```

```
     HDF5  w/o comp.: 0.004209280014038086 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_freak_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_freak)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_freak_40.h5')/1.e6,'MB')
```

```
     HDF5  w/o comp.: 0.0029425621032714844 [s] ... size 0.002408 MB
```

```
del H_left_freak, H_right_freak,keypoints_all_left_freak, keypoints_all_right_freak, descriptors_all_left_freak, descriptors_all_right_freak, points_all_left_freak, points_all_right_freak
```

```
import pickle
Fdb = open('all_feat_surf_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_surf = []
descriptors_all_left_surf = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_surf.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_surf.append(keypoints_each)
  descriptors_all_left_surf.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_surf_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_surf = []
descriptors_all_right_surf = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_surf.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_surf.append(keypoints_each)
  descriptors_all_right_surf.append(descrip_each)
```

```
H_left_surf = []
H_right_surf = []

num_matches_surf = []
num_good_matches_surf = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_surf[j:j+2][::-1],points_all_left_surf[j:j+2][::-1],descriptors_all_left_surf[j:j+2][::-1],0.65)
  H_left_surf.append(H_a)
  num_matches_surf.append(matches)
  num_good_matches_surf.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_surf[j:j+2][::-1],points_all_right_surf[j:j+2][::-1],descriptors_all_right_surf[j:j+2][::-1],0.65)
  H_right_surf.append(H_a)
  num_matches_surf.append(matches)
  num_good_matches_surf.append(gd_matches)
```

```
 17%|█▋        | 1/6 [00:02<00:10,  2.04s/it]
Number of matches 36041
Number of matches After Lowe's Ratio 1688
Number of Robust matches 925


 33%|███▎      | 2/6 [00:04<00:08,  2.17s/it]
Number of matches 37450
Number of matches After Lowe's Ratio 1668
Number of Robust matches 894


 50%|█████     | 3/6 [00:06<00:06,  2.18s/it]
Number of matches 38454
Number of matches After Lowe's Ratio 979
Number of Robust matches 521


 67%|██████▋   | 4/6 [00:09<00:04,  2.28s/it]
Number of matches 38388
Number of matches After Lowe's Ratio 2387
Number of Robust matches 1323


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 38521
Number of matches After Lowe's Ratio 188
Number of Robust matches 57


 17%|█▋        | 1/6 [00:02<00:10,  2.12s/it]
Number of matches 35997
Number of matches After Lowe's Ratio 612
```

```
    Number of Robust matches 411


     33%|███        | 2/6 [00:04<00:08,  2.25s/it]
    Number of matches 38691
    Number of matches After Lowe's Ratio 1115
    Number of Robust matches 726


     50%|█████     | 3/6 [00:07<00:06,  2.31s/it]
    Number of matches 37529
    Number of matches After Lowe's Ratio 5154
    Number of Robust matches 3979


     67%|██████▋   | 4/6 [00:09<00:04,  2.38s/it]
    Number of matches 38125
    Number of matches After Lowe's Ratio 3299
    Number of Robust matches 2454


     83%|████████▎ | 5/6 [00:12<00:02,  2.39s/it]
    Number of matches 39522
    Number of matches After Lowe's Ratio 3394
    Number of Robust matches 2714
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_surf_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_surf)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_surf_40.h5')/1.e6,'MB')
```

```
    HDF5  w/o comp.: 0.0034592151641845703 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_surf_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_surf)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_surf_40.h5')/1.e6,'MB')
```

```
    HDF5  w/o comp.: 0.0033152103424072266 [s] ... size 0.002408 MB
```

```
del H_left_surf, H_right_surf,keypoints_all_left_surf, keypoints_all_right_surf, descriptors_all_left_surf, descriptors_all_right_surf, points_all_left_surf, points_all_right_surf
```

```
import pickle
Fdb = open('all_feat_rootsift_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_rootsift = []
descriptors_all_left_rootsift = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1], _size=kpt_img[1], _angle=kpt_img[2],
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_rootsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_rootsift.append(keypoints_each)
  descriptors_all_left_rootsift.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_rootsift_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_rootsift = []
descriptors_all_right_rootsift = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_rootsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_rootsift.append(keypoints_each)
  descriptors_all_right_rootsift.append(descrip_each)
```

```
H_left_rootsift = []
H_right_rootsift = []

num_matches_rootsift = []
num_good_matches_rootsift = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_rootsift[j:j+2][::-1],points_all_left_rootsift[j:j+2][::-1],descriptors_all_left_rootsift[j:j+2][::-1],0.7)
  H_left_rootsift.append(H_a)
  num_matches_rootsift.append(matches)
  num_good_matches_rootsift.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_rootsift[j:j+2][::-1],points_all_right_rootsift[j:j+2][::-1],descriptors_all_right_rootsift[j:j+2][::-1],0.7)
  H_right_rootsift.append(H_a)
  num_matches_rootsift.append(matches)
  num_good_matches_rootsift.append(gd_matches)
```

```
  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 30579
Number of matches After Lowe's Ratio 3120
 17%|██        | 1/6 [00:03<00:15,  3.07s/it]Number of Robust matches 1935


 33%|███▎      | 2/6 [00:06<00:12,  3.09s/it]
```

```
Number of matches 29556
Number of matches After Lowe's Ratio 4665
Number of Robust matches 2781


 50%|█████     | 3/6 [00:09<00:09,  3.01s/it]
Number of matches 30860
Number of matches After Lowe's Ratio 2527
Number of Robust matches 1391


 67%|██████▋   | 4/6 [00:12<00:06,  3.10s/it]
Number of matches 30396
Number of matches After Lowe's Ratio 4178
Number of Robust matches 2085


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 26655
Number of matches After Lowe's Ratio 1049
Number of Robust matches 501


 17%|█▋        | 1/6 [00:03<00:15,  3.06s/it]
Number of matches 30376
Number of matches After Lowe's Ratio 3608
Number of Robust matches 2719


 33%|███▎      | 2/6 [00:06<00:12,  3.13s/it]
Number of matches 30770
Number of matches After Lowe's Ratio 3217
Number of Robust matches 2474


 50%|█████     | 3/6 [00:09<00:09,  3.15s/it]
Number of matches 30356
Number of matches After Lowe's Ratio 4290
Number of Robust matches 2991


 67%|██████▋   | 4/6 [00:12<00:06,  3.07s/it]
Number of matches 28897
Number of matches After Lowe's Ratio 3191
Number of Robust matches 2431


 83%|████████▎ | 5/6 [00:15<00:03,  3.03s/it]
Number of matches 27133
Number of matches After Lowe's Ratio 3088
Number of Robust matches 2645
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_rootsift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_rootsift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_rootsift_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.005871295928955078 [s] ... size 0.002408 MB
```

```
import h5py as h5
```

```
f=h5.File('drive/MyDrive/H_right_rootsift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_rootsift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_rootsift_40.h5')/1.e6,'MB')
```

```
     HDF5  w/o comp.: 0.0042476654052734375 [s] ... size 0.002408 MB
```

```
del H_left_rootsift, H_right_rootsift,keypoints_all_left_rootsift, keypoints_all_right_rootsift, descriptors_all_left_rootsift, descriptors_all_right_rootsift, points_all_left_rootsift, points_all_right_rootsift
```

```
import pickle
Fdb = open('all_feat_surfsift_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_surfsift = []
descriptors_all_left_surfsift = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_surfsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_surfsift.append(keypoints_each)
  descriptors_all_left_surfsift.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_surfsift_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_surfsift = []
descriptors_all_right_surfsift = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_surfsift.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_surfsift.append(keypoints_each)
  descriptors_all_right_surfsift.append(descrip_each)
```

```
H_left_surfsift = []
H_right_surfsift = []
H_right_surfsift = []

num_matches_surfsift = []
num_good_matches_surfsift = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_surfsift[j:j+2][::-1],points_all_left_surfsift[j:j+2][::-1],descriptors_all_left_surfsift[j:j+2][::-1],0.7,6)
  H_left_surfsift.append(H_a)
  num_matches_surfsift.append(matches)
  num_good_matches_surfsift.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_surfsift[j:j+2][::-1],points_all_right_surfsift[j:j+2][::-1],descriptors_all_right_surfsift[j:j+2][::-1],0.7,6)
  H_right_surfsift.append(H_a)
  num_matches_surfsift.append(matches)
  num_good_matches_surfsift.append(gd_matches)
```

```
 17%|██        | 1/6 [00:03<00:18,  3.73s/it]
Number of matches 36041
Number of matches After Lowe's Ratio 2172
Number of Robust matches 1256


 33%|███▎      | 2/6 [00:08<00:15,  3.92s/it]
Number of matches 37450
Number of matches After Lowe's Ratio 1410
Number of Robust matches 835


 50%|█████     | 3/6 [00:12<00:12,  4.06s/it]
Number of matches 38454
Number of matches After Lowe's Ratio 781
Number of Robust matches 373


 67%|██████▋   | 4/6 [00:17<00:08,  4.24s/it]
Number of matches 38388
Number of matches After Lowe's Ratio 2284
Number of Robust matches 1088


  0%|          | 0/6 [00:00<?, ?it/s]
Number of matches 38521
Number of matches After Lowe's Ratio 87
Number of Robust matches 51


 17%|██        | 1/6 [00:04<00:20,  4.08s/it]
Number of matches 35997
Number of matches After Lowe's Ratio 682
Number of Robust matches 539


 33%|███▎      | 2/6 [00:08<00:16,  4.09s/it]
Number of matches 38691
Number of matches After Lowe's Ratio 1092
Number of Robust matches 778


 50%|█████     | 3/6 [00:12<00:12,  4.26s/it]
```

```
Number of matches 37529
Number of matches After Lowe's Ratio 7009
Number of Robust matches 5112


 67%|██████▋   | 4/6 [00:16<00:08,  4.22s/it]
Number of matches 38125
Number of matches After Lowe's Ratio 3946
Number of Robust matches 2574


 83%|████████▎ | 5/6 [00:21<00:04,  4.38s/it]
Number of matches 39522
Number of matches After Lowe's Ratio 4182
Number of Robust matches 3166
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_surfsift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_surfsift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_surfsift_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0018682479858398438 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_surfsift_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_surfsift)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_surfsift_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0054473876953125 [s] ... size 0.002408 MB
```

```
del H_left_surfsift, H_right_surfsift,keypoints_all_left_surfsift, keypoints_all_right_surfsift, descriptors_all_left_surfsift, descriptors_all_right_surfsift, points_all_left_surfsift, points_all_right_surfsift
```

```
import pickle
Fdb = open('all_feat_gftt_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_gftt = []
descriptors_all_left_gftt = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                        _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_gftt.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_gftt.append(keypoints_each)
  descriptors_all_left_gftt.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_gftt_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_gftt = []
descriptors_all_right_gftt = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_gftt.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_gftt.append(keypoints_each)
  descriptors_all_right_gftt.append(descrip_each)
```

```
H_left_gftt = []
H_right_gftt = []

num_matches_gftt = []
num_good_matches_gftt = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_gftt[j:j+2][::-1],points_all_left_gftt[j:j+2][::-1],descriptors_all_left_gftt[j:j+2][::-1],0.7,6)
  H_left_gftt.append(H_a)
  num_matches_gftt.append(matches)
  num_good_matches_gftt.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_gftt[j:j+2][::-1],points_all_right_gftt[j:j+2][::-1],descriptors_all_right_gftt[j:j+2][::-1],0.7,6)
  H_right_gftt.append(H_a)
  num_matches_gftt.append(matches)
  num_good_matches_gftt.append(gd_matches)
```

```
 67%|██████    | 4/6 [00:00<00:00, 19.05it/s]
Number of matches 1000
Number of matches After Lowe's Ratio 183
Number of Robust matches 129



Number of matches 1000
Number of matches After Lowe's Ratio 265
Number of Robust matches 186



Number of matches 1000
Number of matches After Lowe's Ratio 127
Number of Robust matches 73



Number of matches 1000
Number of matches After Lowe's Ratio 234
Number of Robust matches 131


 67%|██████▋   | 4/6 [00:00<00:00, 13.59it/s]
 33%|███▎      | 2/6 [00:00<00:00, 18.79it/s]
Number of matches 1000
Number of matches After Lowe's Ratio 41
Number of Robust matches 17


Number of matches After Lowe's Ratio New 170
Number of Robust matches New 39



Number of matches 1000
Number of matches After Lowe's Ratio 128
Number of Robust matches 116



Number of matches 1000
Number of matches After Lowe's Ratio 128
Number of Robust matches 109



Number of matches 1000
Number of matches After Lowe's Ratio 249
Number of Robust matches 221


 67%|██████▋   | 4/6 [00:00<00:00, 15.23it/s]
Number of matches 1000
Number of matches After Lowe's Ratio 184
Number of Robust matches 166
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_gftt_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_gftt)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_gftt_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.004757881164550781 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_gftt_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_gftt)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_gftt_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.003325223922729492 [s] ... size 0.002408 MB
```

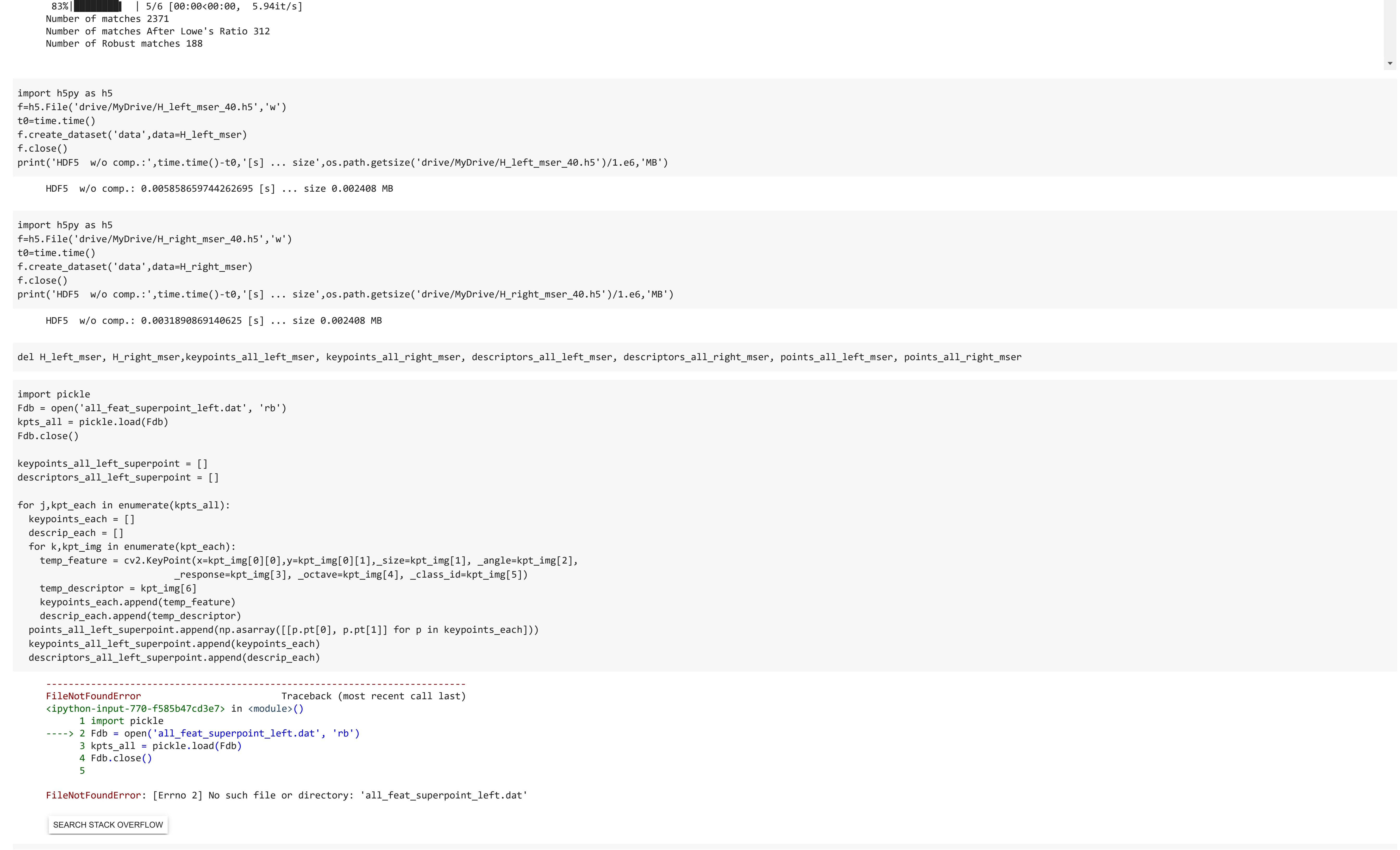
```
del H_left_gftt, H_right_gftt,keypoints_all_left_gftt, keypoints_all_right_gftt, descriptors_all_left_gftt, descriptors_all_right_gftt, points_all_left_gftt, points_all_right_gftt
```

```
import pickle
Fdb = open('all_feat_mser_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_mser = []
descriptors_all_left_mser = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_mser.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_mser.append(keypoints_each)
  descriptors_all_left_mser.append(descrip_each)
```

```
import pickle
Fdb = open('all_feat_mser_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_mser = []
descriptors_all_right_mser = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_mser.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_mser.append(keypoints_each)
  descriptors_all_right_mser.append(descrip_each)
```

```
H_left_mser = []
H_right_mser = []

num_matches_mser = []
num_good_matches_mser = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_mser[j:j+2][::-1],points_all_left_mser[j:j+2][::-1],descriptors_all_left_mser[j:j+2][::-1],0.7,6)
  H_left_mser.append(H_a)
  num_matches_mser.append(matches)
  num_good_matches_mser.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_mser[j:j+2][::-1],points_all_right_mser[j:j+2][::-1],descriptors_all_right_mser[j:j+2][::-1],0.7,6)
  H_right_mser.append(H_a)
  num_matches_mser.append(matches)
  num_good_matches_mser.append(gd_matches)
```

```
 17%|██        | 1/6 [00:00<00:00,  5.34it/s]
Number of matches 3115
Number of matches After Lowe's Ratio 262
Number of Robust matches 127


 33%|███       | 2/6 [00:00<00:00,  5.10it/s]
Number of matches 3244
Number of matches After Lowe's Ratio 321
Number of Robust matches 155


 50%|█████     | 3/6 [00:00<00:00,  4.96it/s]
Number of matches 3304
Number of matches After Lowe's Ratio 185
Number of Robust matches 92


 67%|██████▋   | 4/6 [00:00<00:00,  4.80it/s]
Number of matches 3293
Number of matches After Lowe's Ratio 444
Number of Robust matches 194


 83%|████████▎ | 5/6 [00:01<00:00,  4.64it/s]
 17%|██        | 1/6 [00:00<00:00,  5.69it/s]
Number of matches 3152
Number of matches After Lowe's Ratio 42
Number of Robust matches 22


Number of matches After Lowe's Ratio New 172
Number of Robust matches New 51



Number of matches 2717
Number of matches After Lowe's Ratio 145
Number of Robust matches 92


 50%|█████     | 3/6 [00:00<00:00,  5.78it/s]
Number of matches 2869
Number of matches After Lowe's Ratio 205
Number of Robust matches 124



Number of matches 2594
Number of matches After Lowe's Ratio 492
Number of Robust matches 339
```



```
 83%|████████  | 5/6 [00:00<00:00,  5.94it/s]
Number of matches 2371
Number of matches After Lowe's Ratio 312
Number of Robust matches 188
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_mser_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_mser)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_mser_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.005858659744262695 [s] ... size 0.002408 MB
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_mser_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_mser)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_mser_40.h5')/1.e6,'MB')
```

```
HDF5  w/o comp.: 0.0031890869140625 [s] ... size 0.002408 MB
```

```
del H_left_mser, H_right_mser,keypoints_all_left_mser, keypoints_all_right_mser, descriptors_all_left_mser, descriptors_all_right_mser, points_all_left_mser, points_all_right_mser
```

```
import pickle
Fdb = open('all_feat_superpoint_left.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_left_superpoint = []
descriptors_all_left_superpoint = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_left_superpoint.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_left_superpoint.append(keypoints_each)
  descriptors_all_left_superpoint.append(descrip_each)
```

```
---------------------------------------------------------------------------
FileNotFoundError                         Traceback (most recent call last)
<ipython-input-770-f585b47cd3e7> in <module>()
      1 import pickle
----> 2 Fdb = open('all_feat_superpoint_left.dat', 'rb')
      3 kpts_all = pickle.load(Fdb)
      4 Fdb.close()
      5 

FileNotFoundError: [Errno 2] No such file or directory: 'all_feat_superpoint_left.dat'
```

```
import pickle
Fdb = open('all_feat_superpoint_right.dat', 'rb')
kpts_all = pickle.load(Fdb)
Fdb.close()

keypoints_all_right_superpoint = []
descriptors_all_right_superpoint = []

for j,kpt_each in enumerate(kpts_all):
  keypoints_each = []
  descrip_each = []
  for k,kpt_img in enumerate(kpt_each):
    temp_feature = cv2.KeyPoint(x=kpt_img[0][0],y=kpt_img[0][1],_size=kpt_img[1], _angle=kpt_img[2],
                            _response=kpt_img[3], _octave=kpt_img[4], _class_id=kpt_img[5])
    temp_descriptor = kpt_img[6]
    keypoints_each.append(temp_feature)
    descrip_each.append(temp_descriptor)
  points_all_right_superpoint.append(np.asarray([[p.pt[0], p.pt[1]] for p in keypoints_each]))
  keypoints_all_right_superpoint.append(keypoints_each)
  descriptors_all_right_superpoint.append(descrip_each)
```

```
H_left_superpoint = []
H_right_superpoint = []

num_matches_superpoint = []
num_good_matches_superpoint = []

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

  H_a,matches,gd_matches = get_Hmatrix(images_left_bgr[j:j+2][::-1],keypoints_all_left_superpoint[j:j+2][::-1],points_all_left_superpoint[j:j+2][::-1],descriptors_all_left_superpoint[j:j+2][::-1],ratio=0.8,thresh=3,no_ransac=False,use_lowe=False)
  H_left_superpoint.append(H_a)
  num_matches_superpoint.append(matches)
  num_good_matches_superpoint.append(gd_matches)

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

  H_a,matches,gd_matches = get_Hmatrix(images_right_bgr[j:j+2][::-1],keypoints_all_right_superpoint[j:j+2][::-1],points_all_right_superpoint[j:j+2][::-1],descriptors_all_right_superpoint[j:j+2][::-1],ratio=0.8,thresh = 3,no_ransac=False,use_lowe=
  H_right_superpoint.append(H_a)
  num_matches_superpoint.append(matches)
  num_good_matches_superpoint.append(gd_matches)
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_left_superpoint_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_left_superpoint)
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_left_superpoint_40.h5')/1.e6,'MB')
```

```
import h5py as h5
f=h5.File('drive/MyDrive/H_right_superpoint_40.h5','w')
t0=time.time()
f.create_dataset('data',data=H_right_superpoint)
f.close()
```

```
f.close()
print('HDF5  w/o comp.:',time.time()-t0,'[s] ... size',os.path.getsize('drive/MyDrive/H_right_superpoint_40.h5')/1.e6,'MB')
```

```
del H_left_superpoint, H_right_superpoint,keypoints_all_left_superpoint, keypoints_all_right_superpoint, descriptors_all_left_superpoint, descriptors_all_right_superpoint, points_all_left_superpoint, points_all_right_superpoint
```

```
print(len(num_matches_superpoint))
```

Evaluation Criteria/Performance Metrics for each Dataset:

- **Total Number of Keypoints/Descriptors** detected for dataset (Higher the better) (Plot for 16 are above) for each detector/descriptor
- **Total Number of Matches** (Higher the better) for each detector/descriptor (Plot for 9 below)
- **Total Number of Good Matches after Lowe ratio and RANSAC** (Higher the better) for each detector/descriptor (Plot for 9 Below)
- **Recall rate** which is the Percentage of Good Matches (Higher the Better) from all total matches b/w corresponding images by each detector/descriptor (Plot for 9 Below)
- **1-Precision rate** which signifies Percentage of False matches (Lower the Better) from each detector/descriptor (Plot for 9 Below)
- **F-Score** which which is the Geometric Mean b/w Recall and Precision rate for matches b/w corresponding images (Higher the Better) from each detector/descriptor (Plot for 9 Below)
- **Time** taken by each descriptor/detector (Lower the Better) (Will Plot this after optimization)

Collect All Number Of KeyPoints

```
len_files = len(left_files_path) + len(right_files_path[1:])
num_detectors = 16
Dataset = 'University Campus'
```

```
d = {'Dataset': [f'{Dataset}']*(num_detectors*len_files), 'Number of Keypoints': num_kps_agast + num_kps_akaze + num_kps_brisk + num_kps_daisy + num_kps_fast + num_kps_freak + num_kps_gftt + num_kps_kaze + num_kps_mser + num_kps_orb + num_kps_root
df_numkey_16 = pd.DataFrame(data=d)
df_numkey_16['Number of Keypoints'] = df_numkey_16['Number of Keypoints']/(len_files)
```

```
#d = {'Dataset': ['University Campus']*(3*len_files), 'Number of Keypoints': num_kps_rootsift + num_kps_superpoint + num_kps_surf, 'Detector/Descriptor':['ROOTSIFT']*101 + ['SuperPoint']*101 + ['SURF']*101  }
#df = pd.DataFrame(data=d)
```

```
#df_13 = pd.read_csv('drive/MyDrive/Num_Key_13.csv')
#frames = [df_13, df]
#df_16 = pd.concat(frames)
```

```
#df_16.to_csv('drive/MyDrive/Num_Key_16.csv')
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_numkey_16, kind="bar",
    x="Dataset", y="Number of Keypoints", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=6, aspect=2
)
g.despine(left=True)
g.set_axis_labels("Dataset", "Number of Keypoints/Descriptors")
```

```
g.set_axis_labels("Dataset", "Number of Keypoints/Descriptors")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("Number of Keypoints Detected for each Detector/Descriptor in Different Aerial Datasets")
```

```
g.savefig('drive/MyDrive/Num_Kypoints_16.png')
```

```
df_numkey_16.to_csv('drive/MyDrive/Num_Kypoints_16.csv')
```

Total Number of Matches Detected for each Detector+Descriptor

```
#df_match_16['Number of Total Matches'] =  num_matches_agast + num_matches_akaze + num_matches_brisk + num_matches_daisy + num_matches_fast + num_matches_freak + num_matches_gftt + num_matches_kaze + num_matches_mser + num_matches_orb + num_matche
d = {'Dataset': [f'{Dataset}']*(num_detectors*(len_files-1)), 'Number of Total Matches': num_matches_agast + num_matches_akaze + num_matches_brisk + num_matches_daisy + num_matches_fast + num_matches_freak + num_matches_gftt + num_matches_kaze + n
df_match_16 = pd.DataFrame(data=d)
df_match_16['Number of Total Matches'] = df_match_16['Number of Total Matches']/(len_files-1)
```

```
 import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_match_16, kind="bar",
    x="Dataset", y="Number of Total Matches", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset ", "Total Number of Matches b/w Consecutive/Overlapping Images")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("Total Number of Matches Detected for each Detector/Descriptor in Different Aerial Datasets")
```

```
g.savefig('drive/MyDrive/Num_Matches_16.png')
```

```
#df_match_16.to_csv('drive/MyDrive/Num_Matches_16.csv')
```

Total Number of Good/Robust Matches (NN+Lowe+RANSAC) Detected for each Detector+Descriptor

```
df_match_16['Number of Good Matches'] = num_good_matches_agast + num_good_matches_akaze + num_good_matches_brisk + num_good_matches_daisy + num_good_matches_fast + num_good_matches_freak + num_good_matches_gftt + num_good_matches_kaze + num_good_m
df_match_16['Number of Good Matches'] = df_match_16['Number of Good Matches']/(len_files-1)
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_match_16, kind="bar",
    x="Dataset", y="Number of Good Matches", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset", "Number of Good Matches b/w Consecutive/Overlapping Images")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("Number of Good Matches (Lowe + RANSAC) Detected for each Detector/Descriptor in Different Aerial Datasets")
```

```
g.savefig('drive/MyDrive/Num_Good_Matches_16.png')
```

```
#df_match_16.to_csv('drive/MyDrive/Num_Good_Matches_16.csv')
```

Recall Rate for each Detector+Descriptor

```
df_match_16['Recall Rate of Matches'] = df_match_16['Number of Good Matches']/df_match_16['Number of Total Matches']
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


g = sns.catplot(
    data=df_match_16, kind="bar",
    x="Dataset", y="Recall Rate of Matches", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset", "Precision of Matches")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("Recall Rate of Matches Detected (Good/Total) for each Detector/Descriptor in Different Aerial Datasets (Higher the Better)")
```

```
g.savefig('drive/MyDrive/Recall_Rate_Matches_16.png')
```

1-Precision Rate for each Detector+Descriptor

```
df_match_16['1 - Precision Rate of Matches'] = (df_match_16['Number of Total Matches'] - df_match_16['Number of Good Matches'])/df_match_16['Number of Total Matches']
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_match_16, kind="bar",
    x="Dataset", y="1 - Precision Rate of Matches", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset (100 Images)", "1 - Precision Rate of Matches")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("1 - Precision rate of Matches Detected (False/Total Matches) for each Detector/Descriptor in Different Aerial Datasets (Lower the Better)")
```

```
g.savefig('drive/MyDrive/One_minus_Precision_Rate_Matches_16.png')
```

F-Score for each Detector+Descriptor

```
df_match_16['F-Score'] = (2* (1 - df_match_16['1 - Precision Rate of Matches']) * df_match_16['Recall Rate of Matches'])/((1 - df_match_16['1 - Precision Rate of Matches']) + df_match_16['Recall Rate of Matches'])
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_match_16, kind="bar",
    x="Dataset", y="F-Score", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset", "F-Score")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("F-Score of Matches Detected (2*P*R/P+R) for each Detector/Descriptor in Different Aerial Datasets (Higher the Better)")
```

```
g.savefig('drive/MyDrive/F_Score_Rate_Matches_16.png')
```

```
df_match_16.to_csv('drive/MyDrive/All_metrics_16.csv')
```

Time for each Detector+Descriptor

```
d = {'Dataset': [f'{Dataset}']*(num_detectors), 'Time':  [time_all[7]] + [time_all[3]] + [time_all[0]] + [time_all[5]] + [time_all[10]] + [time_all[8]] + [time_all[9]] + [time_all[2]] + [time_all[6]] + [time_all[1]] + [time_all[14]] + [time_all[12
df_time_16 = pd.DataFrame(data=d)
```

```
print(df_time_16)
```

```
               Dataset        Time Detector/Descriptor
0   University Campus   15.858636          AGAST+SIFT
1   University Campus    8.355230               AKAZE
2   University Campus    8.806531               BRISK
3   University Campus    8.332032          DAISY+SIFT
4   University Campus   11.876412           FAST+SIFT
5   University Campus   13.949200         BRISK+FREAK
6   University Campus    2.277125           GFTT+SIFT
7   University Campus   50.775433                KAZE
8   University Campus   37.917912           MSER+SIFT
9   University Campus    2.673857                 ORB
10  University Campus   16.848440           RootSIFT
11  University Campus   16.547593                SIFT
12  University Campus    1.660578          STAR+BRIEF
13  University Campus   12.318949          SuperPoint
14  University Campus  113.028341                SURF
15  University Campus    8.716111           SURF+SIFT
```

```
import seaborn as sns
sns.set_theme(style='whitegrid')


# Draw a nested barplot by species and sex
g = sns.catplot(
    data=df_time_16, kind="bar",
    x="Dataset", y="Time", hue="Detector/Descriptor",
    ci="sd", palette="Spectral", alpha=.9, height=10, aspect=0.5
)
g.despine(left=True)
g.set_axis_labels("Dataset", "Time (in sec)")
g.legend.set_title("Detector/Descriptor")
g.fig.suptitle("Time taken during Feature Extraction by each Detector/Descriptor in Different Aerial Datasets (Lower the Better)")
```

```
g.savefig('drive/MyDrive/Time_16.png')
```

```
df_time_16.to_csv('drive/MyDrive/Time_16.csv')
```

Stitching with CPU

[ ] ↳ *77 cells hidden*