```
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
```

Importing Drive (Dataset-University)

```
from google.colab import drive

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

```
Mounted at /content/drive
```

```
plt.figure(figsize=(20,10))
```

```
<Figure size 1440x720 with 0 Axes>
<Figure size 1440x720 with 0 Axes>
```

```
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):
  """
  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 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
```

```
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 ImageBounds(img, H):

    h, w= img.shape[0], img.shape[1]
    p1 = np.dot(H, np.array([0, 0, 1]))
    p2 = np.dot(H, np.array([0, h - 1, 1]))
    p3 = np.dot(H, np.array([w - 1, 0, 1]))
    p4 = np.dot(H, np.array([w - 1, h - 1, 1]))
    x1 = p1[0] / p1[2]
    y1 = p1[1] / p1[2]
    x2 = p2[0] / p2[2]
    y2 = p2[1] / p2[2]
    x3 = p3[0] / p3[2]
    y3 = p3[1] / p3[2]
    x4 = p4[0] / p4[2]
    y4 = p4[1] / p4[2]
    minX = math.ceil(min(x1, x2, x3, x4))
    minY = math.ceil(min(y1, y2, y3, y4))
    maxX = math.ceil(max(x1, x2, x3, x4))
    maxY = math.ceil(max(y1, y2, y3, y4))

    return int(minX), int(minY), int(maxX), int(maxY)


def Populate_Images(img, accumulator, H, bw):



    h, w = img.shape[0], img.shape[1]
    minX, minY, maxX, maxY = ImageBounds(img, H)

    for i in range(minX, maxX + 1):
        for j in range(minY, maxY + 1):
            p = np.dot(np.linalg.inv(H), np.array([i, j, 1]))

            x = p[0]
            y = p[1]
            z = p[2]

            _x = int(x / z)
            _y = int(y / z)

            if _x < 0 or _x >= w - 1 or _y < 0 or _y >= h - 1:
                continue

            if img[_y, _x, 0] == 0 and img[_y, _x, 1] == 0 and img[_y, _x, 2] == 0:
                continue
```

```
            wt = 1.0

            if _x >= minX and _x < minX + bw:
                wt = float(_x - minX) /bw
            if _x <= maxX and _x > maxX -bw:
                wt = float(maxX - _x) /bw

            accumulator[j, i, 3] += wt

            for c in range(3):
                accumulator[j, i, c] += img[_y, _x, c] *wt
```

```
def Image_Stitch(Imagesall, blendWidth, accWidth, accHeight, translation):
    channels=3
    #width=720

    acc = np.zeros((accHeight, accWidth, channels + 1))
    M = np.identity(3)
    for count, i in enumerate(Imagesall):
        M = i.position
        img = i.img
        M_trans = translation.dot(M)
        Populate_Images(img, acc, M_trans, blendWidth)

    height, width = acc.shape[0], acc.shape[1]

    img = np.zeros((height, width, 3))
    for i in range(height):
        for j in range(width):
            weights = acc[i, j, 3]
            if weights > 0:
                for c in range(3):
                    img[i, j, c] = int(acc[i, j, c] / weights)


    Imagefull = np.uint8(img)
    M = np.identity(3)
    for count, i in enumerate(Imagesall):
        if count != 0 and count != (len(Imagesall) - 1):
            continue

        M = i.position

        M_trans = translation.dot(M)

        p = np.array([0.5 * width, 0, 1])
        p = M_trans.dot(p)


        if count == 0:
            x_init, y_init = p[:2] / p[2]

        if count == (len(Imagesall) - 1):
            x_final, y_final = p[:2] / p[2]
```

```
    A = np.identity(3)
    croppedImage = cv2.warpPerspective(
        Imagefull, A, (accWidth, accHeight), flags=cv2.INTER_LINEAR
    )
    displayplot(croppedImage, 'Final Stitched Image')
```

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

```
import cv2
print(cv2.__version__)
```

```
4.1.2
```

Reading GPS and Metdata information

Georeferencing through the data (Incomplete)

```
from PIL import Image, ExifTags
img = Image.open(f"{left_files_path[0]}")
exif = { ExifTags.TAGS[k]: v for k, v in img._getexif().items() if k in ExifTags.TAGS }
```

```
from PIL.ExifTags import TAGS

def get_exif(filename):
    image = Image.open(filename)
    image.verify()
    return image._getexif()

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

    return labeled

exif = get_exif(f"{left_files_path[0]}")
labeled = get_labeled_exif(exif)
print(labeled)
```


```
{'ExifVersion': b'0230', 'ApertureValue': (497, 100), 'DateTimeOriginal': '2018:09:02 05:27:46', 'ExposureBiasValue': (0, 10), 'MaxApertureValue': (297, 100), 'SubjectDistance': (4294967295, 1000), 'MeteringMode': 1, 'LightSource': 9, 'Flash
```


```
print(TAGS)
```


```
{11: 'ProcessingSoftware', 254: 'NewSubfileType', 255: 'SubfileType', 256: 'ImageWidth', 257: 'ImageLength', 258: 'BitsPerSample', 259: 'Compression', 262: 'PhotometricInterpretation', 263: 'Thresholding', 264: 'CellWidth', 265: 'CellLength'
```


```
from PIL.ExifTags import GPSTAGS

def get_geotagging(exif):
    if not exif:
```

```
        raise ValueError("No EXIF metadata found")

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

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

Extracting Geotags from each image

```
all_files_path = left_files_path[::-1] + right_files_path[1:]
for file1 in all_files_path:
  exif = get_exif(f"{file1}")
  geotags = get_geotagging(exif)
  #print(geotags)
```

```
def get_decimal_from_dms(dms, ref):

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

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

    return round(degrees + minutes + seconds, 5)

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

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

    return (lat,lon)
```

```
all_geocoords = []
plt.figure(figsize = (20,10))
for file1 in all_files_path:
  exif = get_exif(f"{file1}")
  geotags = get_geotagging(exif)
  #print(get_coordinates(geotags))
  geocoord = get_coordinates(geotags)
  all_geocoords.append(geocoord)
  plt.scatter(x=geocoord[0], y=geocoord[1])
```


```
!pip install gmplot
```

```
Requirement already satisfied: gmplot in /usr/local/lib/python3.7/dist-packages (1.4.1)
Requirement already satisfied: requests in /usr/local/lib/python3.7/dist-packages (from gmplot) (2.23.0)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist-packages (from requests->gmplot) (2.10)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /usr/local/lib/python3.7/dist-packages (from requests->gmplot) (1.24.3)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.7/dist-packages (from requests->gmplot) (3.0.4)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.7/dist-packages (from requests->gmplot) (2020.12.5)
```

```
print(all_geocoords[0])
```

```
(14.06462, 100.61807)
```

```
import gmplot

# Create the map plotter:
apikey = 'AIzaSyDSvwNbHrZIKZSwuQkdAgxc6ONmJ_k5Q20' # (your API key here)
gmap = gmplot.GoogleMapPlotter(all_geocoords[0][0], all_geocoords[0][1], 14, apikey=apikey)

attractions = zip(*[
    (37.769901, -122.498331),
    (37.768645, -122.475328),
    (37.771478, -122.468677),
    (37.769867, -122.466102),
    (37.767187, -122.467496),
    (37.770104, -122.470436)
])

gmap.scatter(
    *attractions,
    color=['red', 'orange', 'yellow', 'green', 'blue', 'purple'],
    s=60,
    ew=2,
```

```
    marker=[True, True, False, True, False, False],
    symbol=[None, None, 'o', None, 'x', '+'],
    title=['First', 'Second', None, 'Third', None, None],
    label=['A', 'B', 'C', 'D', 'E', 'F']
)


# Mark a hidden gem:
#gmap.marker(all_geocoords[0][0], all_geocoords[0][1], color='cornflowerblue')
```

```
#len1 = 10
#gmap.scatter(np.array(all_geocoords)[:len1,0], np.array(all_geocoords)[:len1,1], color='#3B0B39', size=40, marker=False)
```

```
print(gmap.get())
```

```
gmap.draw('drive/MyDrive/map.html')
```

```
from matplotlib.offsetbox import OffsetImage, AnnotationBbox
```

```
print(len(all_geocoords))
print(len(all_files_path))
```

```
101
101
```

```
print(np.min(np.array(all_geocoords)[:30,1]))
```

```
100.61712
```

```
import matplotlib as mpl
mpl.rcParams['figure.dpi'] = 72
```

```
print(np.min(np.array(all_geocoords)[:len1,1]))
```

```
100.61506
```

```
print(np.max(np.array(all_geocoords)[:len1,1]))
```

```
100.61808
```

Image Registration (100 imgs)

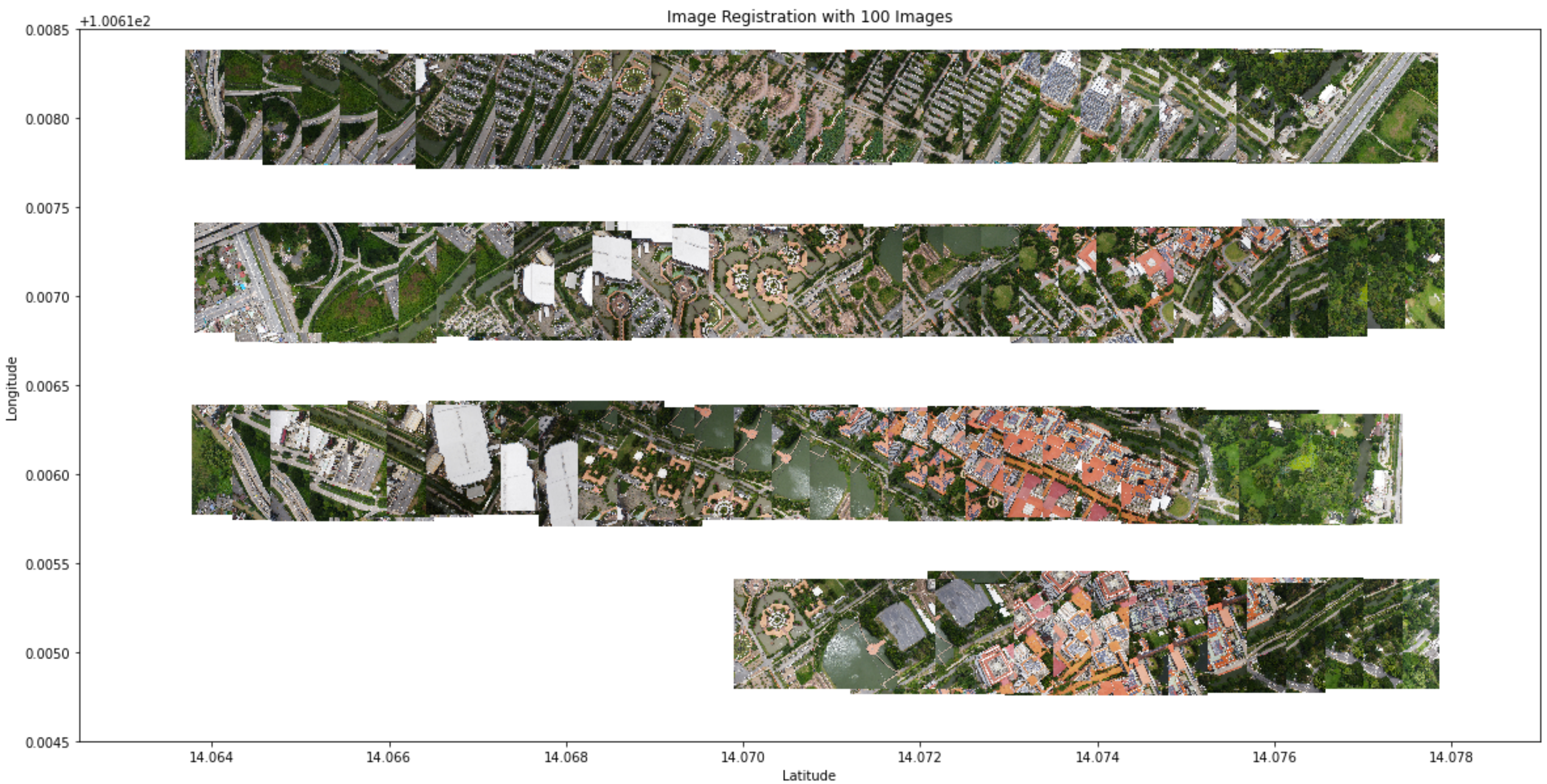
```
fig, ax = plt.subplots()
fig.set_size_inches(20,10)
ax.set_xlabel('Latitude')
ax.set_ylabel('Longitude')
ax.set_ylim(100.6145,100.6185)
len1 = 100
ax.set_title(f'Image Registration with {len1} Images')
ax.set_xlim(14.0625,14.079)

ax.plot(np.array(all_geocoords)[:len1,0], np.array(all_geocoords)[:len1,1],linestyle='None')
```

```
def aerial_images_register(x, y,ax=None):
    ax = ax or plt.gca()
    for count,points in enumerate(zip(x,y)):
        lat,lon = points
        image = plt.imread(all_files_path[count])
        #print(ax.figure.dpi)
        im = OffsetImage(image, zoom=1.5/ax.figure.dpi)
        im.image.axes = ax
        ab = AnnotationBbox(im, (lat,lon), frameon=False, pad=0.0,)

        ax.add_artist(ab)

aerial_images_register(np.array(all_geocoords)[:len1,0], np.array(all_geocoords)[:len1,1], ax=ax)
```



Overlaying on Maps (Incomplete)

```
!pip install gmplot
```

```
import gmplot

# Create the map plotter:
apikey = '' # (your API key here) (Hid the Key because it's a private key)
gmap = gmplot.GoogleMapPlotter(all_geocoords[0][0], all_geocoords[0][1], 14, apikey=apikey)
```

```
# Mark a hidden gem:
#gmap.marker(all_geocoords[0][0], all_geocoords[0][1], color='cornflowerblue')
```

```
len1 = 100
gmap.scatter(np.array(all_geocoords)[:len1,0], np.array(all_geocoords)[:len1,1], color='purple', size=40, marker=[True]*len1)
```

```
gmap.polygon(np.array(all_geocoords)[:len1,0],np.array(all_geocoords)[:len1,1], face_color='blue', edge_color='cornflowerblue', edge_width=10)
```

```
gmap.draw('drive/MyDrive/map14.html')
```

```
fig.savefig('drive/MyDrive/uni_dtset_regist_100_chnged.jpg', dpi=300)
```

```
!pip install pyproj
```

```
Collecting pyproj
  Downloading https://files.pythonhosted.org/packages/11/1d/1c54c672c2faf08d28fe78e15d664c048f786225bef95ad87b6c435cf69e/pyproj-3.1.0-cp37-cp37m-manylinux2010_x86_64.whl (6.6MB)
     |████████████████████████████████| 6.6MB 1.1MB/s
Requirement already satisfied: certifi in /usr/local/lib/python3.7/dist-packages (from pyproj) (2020.12.5)
Installing collected packages: pyproj
Successfully installed pyproj-3.1.0
```

```
import pyproj
from pyproj import Proj
```

```
!pip install GDAL
```

```
Requirement already satisfied: GDAL in /usr/local/lib/python3.7/dist-packages (2.2.2)
```

```
import gdal
```

```
# open the dataset and get the geo transform matrix
ds = gdal.Open((f"{all_files_path[0]}"))
xoff, pix_width, rotatonal, yoff, px_height, rotation_second = ds.GetGeoTransform()
```

```
# Describe source image size
x_height = ds.RasterXSize
y_width = ds.RasterYSize
```

```
p = pyproj.Proj(proj='utm', zone=47, ellps='WGS84')
```

```
lat_file,long_file = get_coordinates(get_geotagging(get_exif(f"{all_files_path[0]}")))
UTM_east, UTM_north = p(long_file, lat_file)
```

```
upper_pix = x_height/2
left_pix = y_width/2
```

```
print(ds.GetMetadata_Dict())
```


```
{'EXIF_ApertureValue': '(4.97)', 'EXIF_DateTimeOriginal': '2018:09:02 05:23:42', 'EXIF_ExifVersion': '0230', 'EXIF_ExposureBiasValue': '(0)', 'EXIF_ExposureProgram': '4', 'EXIF_ExposureTime': '(0.0005)', 'EXIF_Flash': '16', 'EXIF_FlashEnergy
```

```
x_tf = UTM_east - 0.5*pix_area - (pix_area * upper_pix)
y_tf = UTM_north + 0.5*pix_area + (pix_area * left_pix)

print(x_tf,y_tf)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-23-0bc38208523d> in <module>()
----> 1 x_tf = UTM_east - 0.5*pix_area - (pix_area * upper_pix)
      2 y_tf = UTM_north + 0.5*pix_area + (pix_area * left_pix)

NameError: name 'pix_area' is not defined
```

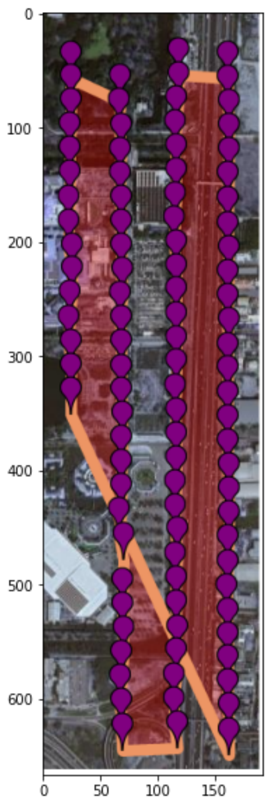
SEARCH STACK OVERFLOW

```
img = cv2.imread('drive/MyDrive/Screenshot_map_with_geolocations.png')
```

```
plt.figure(figsize = (20,10))

plt.imshow(img)
```

```
<matplotlib.image.AxesImage at 0x7fb3328343d0>
```



Getting incorrect results when overlaying images onto the geolocations, will fix tomorrow

Reading images and Extracting SuperPoint Keypoints and Descriptors from each image

↳ 17 cells hidden

Loading and Initialing the SuperPoint Pretrained Network

[ ] ↳ 1 cell hidden

Now Extracting Keypoints and Descriptors from all images and storing them

[ ] ↳ 7 cells hidden

Image Matching (Robust) through RANSAC and Homography Matrix computation

[ ] ↳ 8 cells hidden

Auto-Selection/Ordering of Images (Complete)

[ ] ↳ 20 cells hidden

Perspective Transformation b/w consecutive pairs through the computed Homography Matrices

[ ] ↳ 6 cells hidden

Final Mosaiced Image (with 24 images)

[ ] ↳ 1 cell hidden

To-Do Tasks

- Seam Removal
- Improve On this Enhancement
- Extend to 50 images

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