In [1]:
```
from absl import logging

import matplotlib.pyplot as plt
import numpy as np
from PIL import Image, ImageOps
from scipy.spatial import cKDTree
from skimage.feature import plot_matches
from skimage.measure import ransac
from skimage.transform import AffineTransform
from six import BytesIO

import tensorflow as tf

import tensorflow_hub as hub
from six.moves.urllib.request import urlopen
```

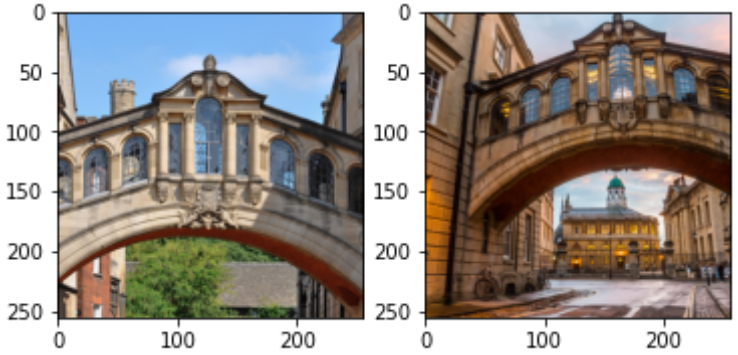
In [2]:
```
images = "Bridge of Sighs"
if images == "Bridge of Sighs":
  # from: https://commons.wikimedia.org/wiki/File:Bridge_of_Sighs,_Oxford.jpg
  # by: N.H. Fischer
  IMAGE_1_URL = 'https://upload.wikimedia.org/wikipedia/commons/2/28/Bridge_of_Sighs%2C_Oxford.jpg'
  # from https://commons.wikimedia.org/wiki/File:The_Bridge_of_Sighs_and_Sheldonian_Theatre,_Oxford.jpg
  # by: Matthew Hoser
  IMAGE_2_URL = 'https://upload.wikimedia.org/wikipedia/commons/c/c3/The_Bridge_of_Sighs_and_Sheldonian_Theatre%2C_Ox
elif images == "Golden Gate":
  IMAGE_1_URL = 'https://upload.wikimedia.org/wikipedia/commons/1/1e/Golden_gate2.jpg'
  IMAGE_2_URL = 'https://upload.wikimedia.org/wikipedia/commons/3/3e/GoldenGateBridge.jpg'
elif images == "Acropolis":
  IMAGE_1_URL = 'https://upload.wikimedia.org/wikipedia/commons/c/ce/2006_01_21_Ath%C3%A8nes_Parth%C3%A9non.JPG'
  IMAGE_2_URL = 'https://upload.wikimedia.org/wikipedia/commons/5/5c/ACROPOLIS_1969_-_panoramio_-_jean_melis.jpg'
else:
  IMAGE_1_URL = 'https://upload.wikimedia.org/wikipedia/commons/d/d8/Eiffel_Tower%2C_November_15%2C_2011.jpg'
  IMAGE_2_URL = 'https://upload.wikimedia.org/wikipedia/commons/a/a8/Eiffel_Tower_from_immediately_beside_it%2C_Paris
```

In [3]:
```
def download_and_resize(name, url, new_width=256, new_height=256):
  path = tf.keras.utils.get_file(url.split('/')[-1], url)
  image = Image.open(path)
  image = ImageOps.fit(image, (new_width, new_height), Image.ANTIALIAS)
  return image
```

In [4]:
```
image1 = download_and_resize('image_1.jpg', IMAGE_1_URL)
image2 = download_and_resize('image_2.jpg', IMAGE_2_URL)

plt.subplot(1,2,1)
plt.imshow(image1)
plt.subplot(1,2,2)
plt.imshow(image2)
```

```
Downloading data from https://upload.wikimedia.org/wikipedia/commons/2/28/Bridge_of_Sighs%2C_Oxford.jpg
7020544/7013850 [==============================] - 0s 0us/step
Downloading data from https://upload.wikimedia.org/wikipedia/commons/c/c3/The_Bridge_of_Sighs_and_Sheldonian_Theatre%2C_Oxford.jpg
14172160/14164194 [==============================] - 1s 0us/step
```

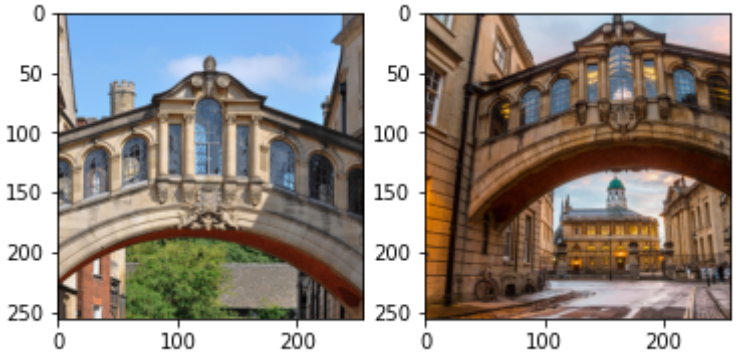
Out[4]:
```
<matplotlib.image.AxesImage at 0x7fa281188810>
```



In [5]:
```
def download_and_resize(name, url, new_width=256, new_height=256):
  path = tf.keras.utils.get_file(url.split('/')[-1], url)
  image = Image.open(path)
  image = ImageOps.fit(image, (new_width, new_height), Image.ANTIALIAS)
  return image
```

In [6]:
```
image1 = download_and_resize('image_1.jpg', IMAGE_1_URL)
image2 = download_and_resize('image_2.jpg', IMAGE_2_URL)

plt.subplot(1,2,1)
plt.imshow(image1)
plt.subplot(1,2,2)
plt.imshow(image2)
```

Out[6]: <matplotlib.image.AxesImage at 0x7fa22a102b10>



In [7]:
```
delf = hub.load('https://tfhub.dev/google/delf/1').signatures['default']
```

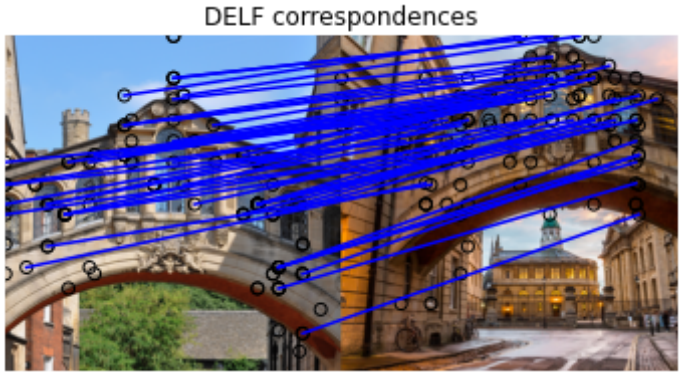
In [8]:
```
def run_delf(image):
  np_image = np.array(image)
  float_image = tf.image.convert_image_dtype(np_image, tf.float32)

  return delf(
      image=float_image,
      score_threshold=tf.constant(100.0),
      image_scales=tf.constant([0.25, 0.3536, 0.5, 0.7071, 1.0, 1.4142, 2.0]),
      max_feature_num=tf.constant(1000))
```

In [9]:
```
result1 = run_delf(image1)
result2 = run_delf(image2)
```

In [10]:
```
def match_images(image1, image2, result1, result2):
  distance_threshold = 0.8

  # Read features.
  num_features_1 = result1['locations'].shape[0]
  print("Loaded image 1's %d features" % num_features_1)

  num_features_2 = result2['locations'].shape[0]
  print("Loaded image 2's %d features" % num_features_2)

  # Find nearest-neighbor matches using a KD tree.
```

```
  d1_tree = cKDTree(result1['descriptors'])
  _, indices = d1_tree.query(
      result2['descriptors'],
      distance_upper_bound=distance_threshold)

  # Select feature locations for putative matches.
  locations_2_to_use = np.array([
      result2['locations'][i,]
      for i in range(num_features_2)
      if indices[i] != num_features_1
  ])
  locations_1_to_use = np.array([
      result1['locations'][indices[i],]
      for i in range(num_features_2)
      if indices[i] != num_features_1
  ])

  # Perform geometric verification using RANSAC.
  _, inliers = ransac(
      (locations_1_to_use, locations_2_to_use),
      AffineTransform,
      min_samples=3,
      residual_threshold=20,
      max_trials=1000)

  print('Found %d inliers' % sum(inliers))

  # Visualize correspondences.
  _, ax = plt.subplots()
  inlier_idxs = np.nonzero(inliers)[0]
  plot_matches(
      ax,
      image1,
      image2,
      locations_1_to_use,
      locations_2_to_use,
      np.column_stack((inlier_idxs, inlier_idxs)),
      matches_color='b')
  ax.axis('off')
  ax.set_title('DELF correspondences')

match_images(image1, image2, result1, result2)
```

```
Loaded image 1's 233 features
Loaded image 2's 262 features
Found 49 inliers
```



In [11]:
```python
import cv2
import numpy as np
import matplotlib.pyplot as plt
import imageio
import imutils
cv2.ocl.setUseOpenCL(False)
```

In [12]:
```python
# select the image id (valid values 1,2,3, or 4)
feature_extractor = 'orb' # one of 'sift', 'surf', 'brisk', 'orb'
feature_matching = 'bf'
```

In [19]:
```python
def createMatcher(method,crossCheck):
    "Create and return a Matcher Object"

    if method == 'sift' or method == 'surf':
        bf = cv2.BFMatcher(cv2.NORM_L2, crossCheck=crossCheck)
    elif method == 'orb' or method == 'brisk':
        bf = cv2.BFMatcher(cv2.NORM_HAMMING, crossCheck=crossCheck)
    return bf
```

In [20]:
```python
def matchKeyPointsBF(featuresA, featuresB, method):
    bf = createMatcher(method, crossCheck=True)

    # Match descriptors.
```

```
    best_matches = bf.match(featuresA,featuresB)

    # Sort the features in order of distance.
    # The points with small distance (more similarity) are ordered first in the vector
    rawMatches = sorted(best_matches, key = lambda x:x.distance)
    print("Raw matches (Brute force):", len(rawMatches))
    return rawMatches
```

In [21]:
```
def matchKeyPointsKNN(featuresA, featuresB, ratio, method):
    bf = createMatcher(method, crossCheck=False)
    # compute the raw matches and initialize the list of actual matches
    rawMatches = bf.knnMatch(featuresA, featuresB, 2)
    print("Raw matches (knn):", len(rawMatches))
    matches = []

    # loop over the raw matches
    for m,n in rawMatches:
        # ensure the distance is within a certain ratio of each
        # other (i.e. Lowe's ratio test)
        if m.distance < n.distance * ratio:
            matches.append(m)
    return matches
```

In [22]:
```
if feature_matching == 'bf':
    matches = matchKeyPointsBF(featuresA, featuresB, method=feature_extractor)
    img3 = cv2.drawMatches(trainImg,kpsA,queryImg,kpsB,matches[:100],
                           None,flags=cv2.DrawMatchesFlags_NOT_DRAW_SINGLE_POINTS)
elif feature_matching == 'knn':
    matches = matchKeyPointsKNN(featuresA, featuresB, ratio=0.75, method=feature_extractor)
    img3 = cv2.drawMatches(trainImg,kpsA,queryImg,kpsB,np.random.choice(matches,100),
                           None,flags=cv2.DrawMatchesFlags_NOT_DRAW_SINGLE_POINTS)
```

```
Raw matches (Brute force): 138
```

In [23]:
```
def getHomography(kpsA, kpsB, featuresA, featuresB, matches, reprojThresh):
    # convert the keypoints to numpy arrays
    kpsA = np.float32([kp.pt for kp in kpsA])
    kpsB = np.float32([kp.pt for kp in kpsB])

    if len(matches) > 4:

        # construct the two sets of points
```

```
        ptsA = np.float32([kpsA[m.queryIdx] for m in matches])
        ptsB = np.float32([kpsB[m.trainIdx] for m in matches])

        # estimate the homography between the sets of points
        (H, status) = cv2.findHomography(ptsA, ptsB, cv2.RANSAC,
            reprojThresh)

        return (matches, H, status)
    else:
        return None
```

In [24]:
```
M = getHomography(kpsA, kpsB, featuresA, featuresB, matches, reprojThresh=4)
if M is None:
    print("Error!")
(matches, H, status) = M
```

In [25]:
```
# Apply panorama correction
width = trainImg.shape[1] + queryImg.shape[1]
height = trainImg.shape[0] + queryImg.shape[0]

result = cv2.warpPerspective(trainImg, H, (width, height))
result[0:queryImg.shape[0], 0:queryImg.shape[1]] = queryImg
```

In [26]:
```
# transform the panorama image to grayscale and threshold it
gray = cv2.cvtColor(result, cv2.COLOR_BGR2GRAY)
thresh = cv2.threshold(gray, 0, 255, cv2.THRESH_BINARY)[1]

# Finds contours from the binary image
cnts = cv2.findContours(thresh.copy(), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
cnts = imutils.grab_contours(cnts)

# get the maximum contour area
c = max(cnts, key=cv2.contourArea)

# get a bbox from the contour area
(x, y, w, h) = cv2.boundingRect(c)

# crop the image to the bbox coordinates
result = result[y:y + h, x:x + w]

# show the cropped image
```

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

Out[26]: <matplotlib.figure.AxesImage at 0x7fa211174290>