Assignment 3

Texture Synthesis

In [2]:
```
from PIL import Image, ImageDraw
import matplotlib.pyplot as plt
from matplotlib.backends.backend_agg import FigureCanvasAgg as FigureCanvas
import numpy as np
import random
import os.path
import pickle
```

Ignore provided code --- answers are below ---------

In [3]:
```
##################################################################################
#                              Some helper functions                             #
##################################################################################

def draw_box(im, x1, y1, x2, y2):
    draw = ImageDraw.Draw(im)
    draw.line((x1, y1, x1, y2), fill="white", width=1)
    draw.line((x1, y1, x2, y1), fill="white", width=1)
    draw.line((x2, y2, x1, y2), fill="white", width=1)
    draw.line((x2, y2, x2, y1), fill="white", width=1)
    del draw
    return im


def find_edge(hole_mask):
    [cols, rows] = np.shape(hole_mask)
    edge_mask = np.zeros(np.shape(hole_mask))
    for y in range(rows):
        for x in range(cols):
            if hole_mask[x, y] == 1:
                if (hole_mask[x - 1, y] == 0 or
                        hole_mask[x + 1, y] == 0 or
                        hole_mask[x, y - 1] == 0 or
                        hole_mask[x, y + 1] == 0):
                    edge_mask[x, y] = 1
    return edge_mask
```

In [4]:
```
################################################################################
#                              Main script starts here                         #
################################################################################

def texture_synthesis(img_path, randomPatchSD, patchL):
    # Constants

    # Change patchL to change the patch size used (patch size is 2 *patchL +
 1)
    patchSize = 2 * patchL + 1

    # Display results interactively
    showResults = True

    # Read input image
    im = Image.open(img_path).convert('RGB')
    im_array = np.asarray(im, dtype=np.uint8)
    imRows, imCols, imBands = np.shape(im_array)

    # Define hole and texture regions.  This will use files fill_region.pkl an
d
    # texture_region.pkl, if both exist, otherwise user has to select the regi
ons.
    imname = os.path.splitext(os.path.basename(img_path))[0]
    print(imname)
    fill_file = 'data/fill_region_{}.pkl'.format(imname)
    texture_file = 'data/texture_region_{}.pkl'.format(imname)
    if os.path.isfile(fill_file) and os.path.isfile(texture_file):
        fill_region_file = open(fill_file, 'rb')
        fillRegion = pickle.load(fill_region_file)
        fill_region_file.close()

        texture_region_file = open(texture_file, 'rb')
        textureRegion = pickle.load(texture_region_file)
        texture_region_file.close()
    else:
        # ask the user to define the regions
        fillRegion, textureRegion = 0, 0
        print("Specify the fill and texture regions using polyselect.py")
        exit()

    # Get coordinates for hole and texture regions
    fill_indices = fillRegion.nonzero()
    nFill = len(fill_indices[0])  # number of pixels to be filled
    iFillMax = max(fill_indices[0])
    iFillMin = min(fill_indices[0])
    jFillMax = max(fill_indices[1])
    jFillMin = min(fill_indices[1])
    assert ((iFillMin >= patchL) and
            (iFillMax < imRows - patchL) and
            (jFillMin >= patchL) and
            (jFillMax < imCols - patchL)), "Hole is too close to edge of image
for this patch size"

    texture_indices = textureRegion.nonzero()
    iTextureMax = max(texture_indices[0])
```

```
    iTextureMin = min(texture_indices[0])
    jTextureMax = max(texture_indices[1])
    jTextureMin = min(texture_indices[1])
    textureIm = im_array[iTextureMin:iTextureMax + 1, jTextureMin:jTextureMax
+ 1, :]
    texImRows, texImCols, texImBands = np.shape(textureIm)
    assert ((texImRows > patchSize) and
            (texImCols > patchSize)), "Texture image is smaller than patch siz
e"

    # Initialize imHole for texture synthesis (i.e., set fill pixels to 0)
    imHole = im_array.copy()
    imHole[fill_indices] = 0

    # Is the user happy with fillRegion and textureIm?
    if showResults:
        # original
        plt.imshow(im)
        plt.show()
        # convert to a PIL image, show fillRegion and draw a box around textur
eIm
        im1 = Image.fromarray(imHole).convert('RGB')
        im1 = draw_box(im1, jTextureMin, iTextureMin, jTextureMax, iTextureMax
)
        plt.imshow(im1)
        plt.show()
        print("Are you happy with this choice of fillRegion and textureIm?")
        Yes_or_No = False
        answer = "No"
        while not Yes_or_No:
            answer = input("Yes or No: ")
            if answer == "Yes" or answer == "No":
                Yes_or_No = True
        assert answer == "Yes", "You must be happy. Please try again."

    # Perform the hole filling
    while nFill > 0:
        print("Number of pixels remaining = ", nFill)

        # Set TODORegion to pixels on the boundary of the current fillRegion
        TODORegion = find_edge(fillRegion)
        edge_pixels = TODORegion.nonzero()
        nTODO = len(edge_pixels[0])

        while nTODO > 0:
            # Pick a random pixel from the TODORegion
            index = np.random.randint(0, nTODO)
            iPatchCenter = edge_pixels[0][index]
            jPatchCenter = edge_pixels[1][index]

            # Define the coordinates for the TODOPatch
            TODOPatch = imHole[iPatchCenter - patchL:iPatchCenter + patchL + 1
,
                               jPatchCenter - patchL:jPatchCenter + patchL + 1, :]
            TODOMask = fillRegion[iPatchCenter - patchL:iPatchCenter + patchL
+ 1,
                                  jPatchCenter - patchL:jPatchCenter + patchL + 1]
```

```
            # Compute masked SSD of TODOPatch and textureIm
            ssdIm = computeSSD(TODOPatch, TODOMask, textureIm, patchL)

            # Randomized selection of one of the best texture patches
            ssdIm1 = np.sort(np.copy(ssdIm), axis=None)
            ssdValue = ssdIm1[min(round(abs(random.gauss(0, randomPatchSD))),
np.size(ssdIm1) - 1)]
            ssdIndex = np.nonzero(ssdIm == ssdValue)
            iSelectCenter = ssdIndex[0][0]
            jSelectCenter = ssdIndex[1][0]

            # adjust i, j coordinates relative to textureIm
            iSelectCenter = iSelectCenter + patchL
            jSelectCenter = jSelectCenter + patchL
            selectPatch = textureIm[iSelectCenter - patchL:iSelectCenter + pat
chL + 1,
                          jSelectCenter - patchL:jSelectCenter + patchL + 1,
:]

            # Copy patch into hole
            imHole = copy_patch(imHole, TODOMask, textureIm, iPatchCenter, jPa
tchCenter,
                                iSelectCenter, jSelectCenter, patchL, selectPa
tch)

            # Update TODORegion and fillRegion by removing locations that over
lapped the patch
            TODORegion[iPatchCenter - patchL:iPatchCenter + patchL + 1, jPatch
Center - patchL:jPatchCenter + patchL + 1] = 0
            fillRegion[iPatchCenter - patchL:iPatchCenter + patchL + 1, jPatch
Center - patchL:jPatchCenter + patchL + 1] = 0

            edge_pixels = TODORegion.nonzero()
            nTODO = len(edge_pixels[0])

        fill_indices = fillRegion.nonzero()
        nFill = len(fill_indices[0])

    # Output results
    if showResults:
        result = Image.fromarray(imHole).convert('RGB')
        plt.imshow(result)
        plt.show()
    Image.fromarray(imHole).convert('RGB').save('output/results_{}.jpg'.format
(imname))
```

In [5]:
```
################################################################################
#                    Driver code for polygon selection                         #
################################################################################

class LineBuilder:

    def __init__(self, line):
        # Prepare for the first click.
        self.line = line
        self.first_click = True
        # Add click listener
        self.cid = self.line.figure.canvas.mpl_connect('button_press_event', s
elf)
        # Add close listener
        self.xs = list()
        self.ys = list()

    def __call__(self, event):

        # Initialize with the first click.
        if self.first_click:
            self.first_click = False
            self.xs.append(int(event.xdata))
            self.ys.append(int(event.ydata))
            self.line.set_data(self.xs, self.ys)
            return

        # Handle further clicks.
        if event.inaxes != self.line.axes:
            return
        self.xs.append(int(event.xdata))
        self.ys.append(int(event.ydata))
        self.line.set_data(self.xs, self.ys)
        self.line.figure.canvas.draw()


def polyselect(img_path):

    # Function that handles closing the viewer
    def handle_close(event):
        xs = event.canvas.figure.linebuilder.xs
        ys = event.canvas.figure.linebuilder.ys
        fillPolyPoint = list()
        for i in range(len(xs)):
            fillPolyPoint.append(xs[i])
            fillPolyPoint.append(ys[i])

        assert len(fillPolyPoint) >= 6, "A polygon requires at least 3 points"
        img = Image.new('L', (ncols, nrows), 0)
        ImageDraw.Draw(img).polygon(fillPolyPoint, outline=1, fill=1)
        fillRegion = np.array(img, dtype=np.uint8)

        # Save the pickle
        ff = open(fname, 'wb')
        pickle.dump(fillRegion, ff, -1)
        ff.close()
```

```
        print('Saved region to {}!'.format(fname))

    # === Read the image
    im = Image.open(img_path).convert('RGB')
    im_array = np.asarray(im, dtype=np.uint8)
    nrows, ncols, _ = im_array.shape

    print('Would you like to select the region to be filled (0) or the sample
 texture region (1)?')

    Zero_or_One = False
    answer = 0
    while not Zero_or_One:
        answer = input("0 or 1: ")
        if answer == "0" or answer == "1":
            Zero_or_One = True

    imname = os.path.splitext(os.path.basename(img_path))[0]
    if answer == "0":
        fname = 'data/fill_region_{}.pkl'.format(imname)
    else:
        fname = 'data/texture_region_{}.pkl'.format(imname)
        print('Note: Code in Holefill.py forces the texture region to be recta
ngular')
    print('Please use your mouse to specify the region that you want for {0}'.
format(fname))
    print('(Click to select each polygon vertex. Close the window to complete
 and save the polygon.)')

    # === Create display
    fig = plt.figure()
    ax = fig.add_subplot(111)
    ax.set_xlim([0, ncols])
    ax.set_ylim([0, nrows])
    ax.invert_yaxis()

    # === Display the image
    ax.imshow(im_array)
    ax.set_title('click to build line segments')

    # === Add listener for close event
    fig.canvas.mpl_connect('close_event', handle_close)

    line, = ax.plot([0], [0])  # empty line
    fig.linebuilder = LineBuilder(line)
    plt.show()
```

Question 4

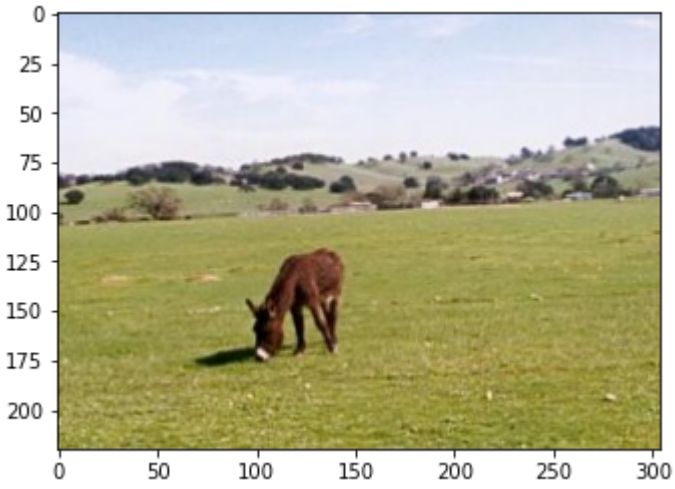
In [6]:
```
def computeSSD(TODOPatch, TODOMask, textureIm, patchL):
    patch_rows, patch_cols, patch_bands = np.shape(TODOPatch)
    tex_rows, tex_cols, tex_bands = np.shape(textureIm)
    ssd_rows = tex_rows - 2 * patchL
    ssd_cols = tex_cols - 2 * patchL
    SSD = np.zeros((ssd_rows, ssd_cols))
    for r in range(ssd_rows):
        for c in range(ssd_cols):
            # Compute sum square difference between textureIm and TODOPatch
            # for all pixels where TODOMask = 0, and store the result in SSD
            if r < TODOMask.shape[0] and c < TODOMask.shape[1]:
                if TODOMask[r, c] == 0:
                    SSD[r, c] = sum((TODOPatch[r, c, :] * 1.0 - textureIm[r, c
, :] * 1.0) ** 2)
    return SSD
```

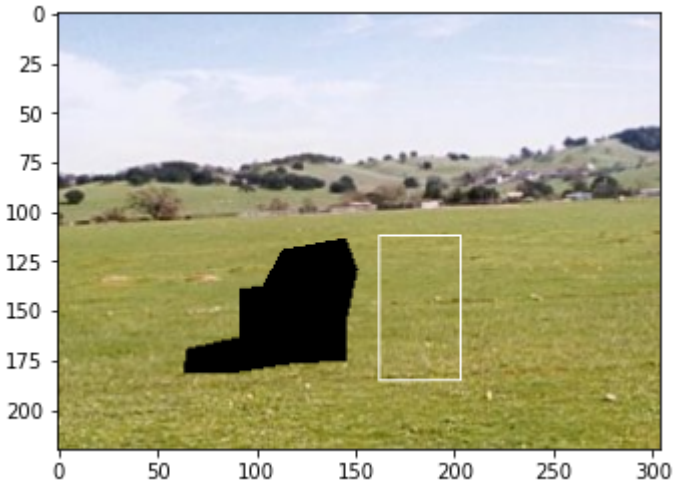
Question 5

In [7]:
```
def copy_patch(imHole, TODOMask, textureIm, iPatchCenter, jPatchCenter, iMatch
Center, jMatchCenter, patchL, selectPatch):
    patchSize = 2 * patchL + 1
    for i in range(patchSize):
        for j in range(patchSize):
            # Copy the selected patch selectPatch into the image containing
            # the hole imHole for each pixel where TODOMask = 1.
            # The patch is centred on iPatchCenter, jPatchCenter in the image
 imHole
            if TODOMask[i, j] == 1:
                imHole[i + iPatchCenter - int(patchSize/2), j + jPatchCenter -
int(patchSize/2)] = selectPatch[i, j]
    return imHole
```

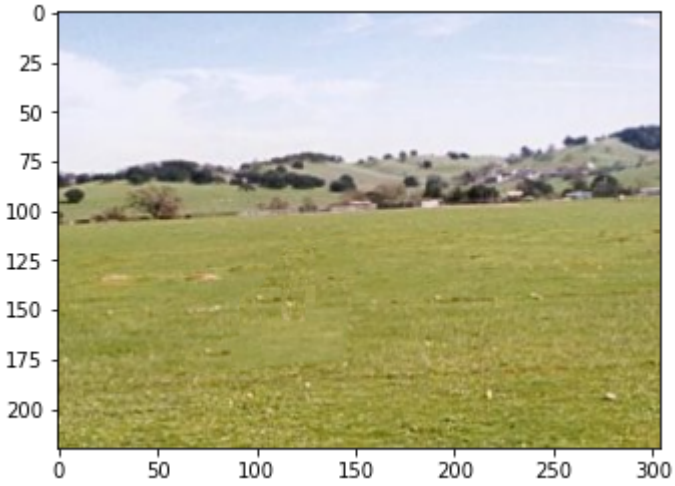
In [8]:
```
%matplotlib inline
texture_synthesis("data/donkey.jpg", randomPatchSD=5, patchL=20)
# texture_synthesis("data/donkey.jpg", randomPatchSD=20, patchL=20)
```

donkey





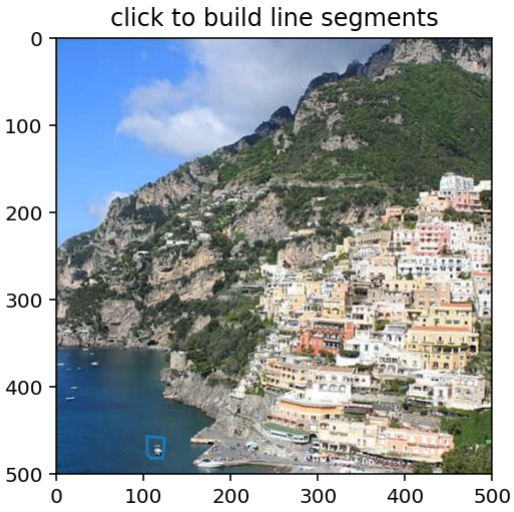

```
Are you happy with this choice of fillRegion and textureIm?
Yes or No: Yes
Number of pixels remaining =  3473
Number of pixels remaining =  204
```



Question 6

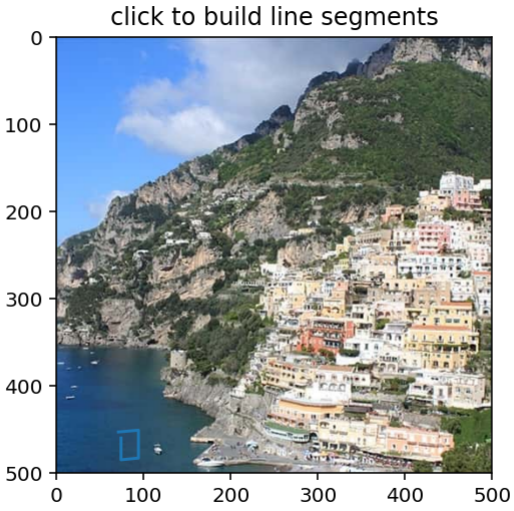
In [11]:
```
%matplotlib notebook
polyselect("data/almafi.jpg")
```

```
Would you like to select the region to be filled (0) or the sample texture re
gion (1)?
0 or 1: 0
Please use your mouse to specify the region that you want for data/fill_regio
n_almafi.pkl
(Click to select each polygon vertex. Close the window to complete and save t
he polygon.)
```



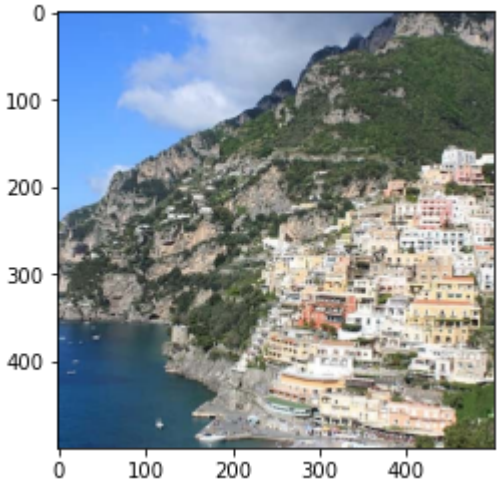
In [12]:
```
%matplotlib notebook
polyselect("data/almafi.jpg")
```

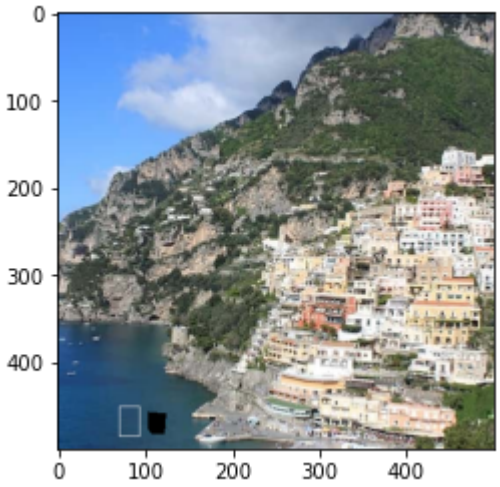
```
Would you like to select the region to be filled (0) or the sample texture re
gion (1)?
0 or 1: 1
Note: Code in Holefill.py forces the texture region to be rectangular
Please use your mouse to specify the region that you want for data/texture_re
gion_almafi.pkl
(Click to select each polygon vertex. Close the window to complete and save t
he polygon.)
```



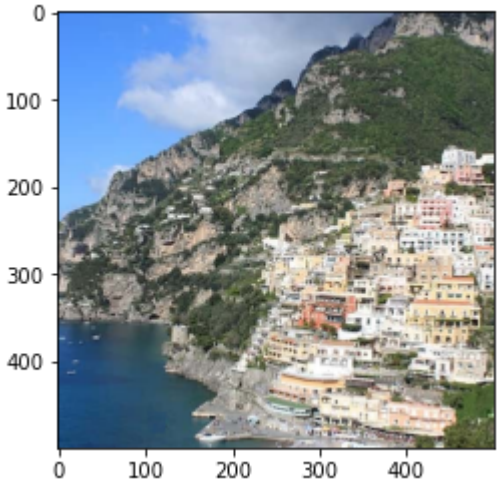
In [15]:
```
%matplotlib inline
texture_synthesis("data/almafi.jpg", randomPatchSD=10, patchL=10)
```

```
almafi
```



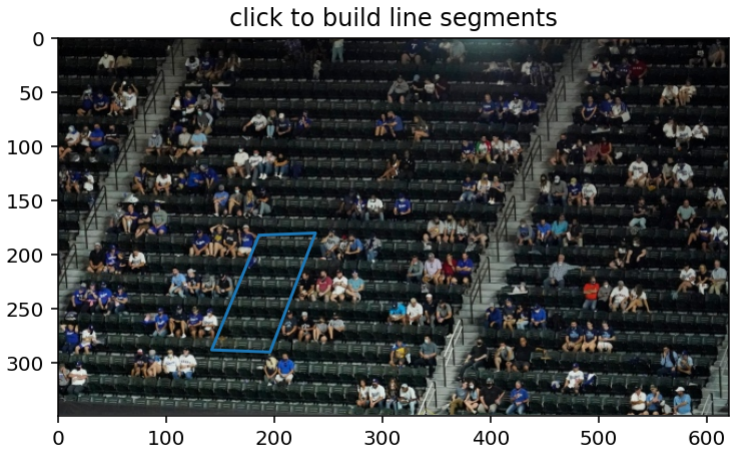



```
Are you happy with this choice of fillRegion and textureIm?
Yes or No: Yes
Number of pixels remaining =  480
```



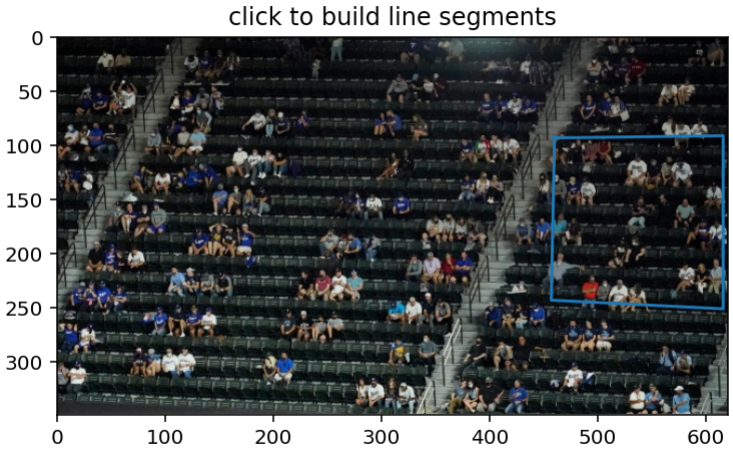
In [23]:
```
%matplotlib notebook
polyselect("data/crowd.jpg")
```

```
Would you like to select the region to be filled (0) or the sample texture re
gion (1)?
0 or 1: 0
Please use your mouse to specify the region that you want for data/fill_regio
n_crowd.pkl
(Click to select each polygon vertex. Close the window to complete and save t
he polygon.)
```



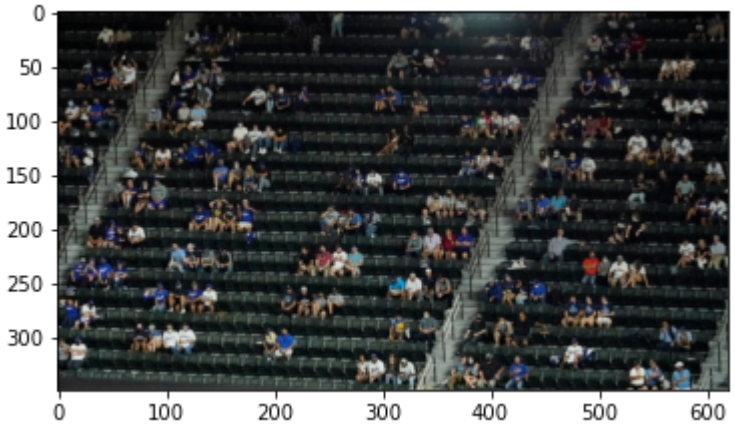
In [27]:
```
%matplotlib notebook
polyselect("data/crowd.jpg")
```

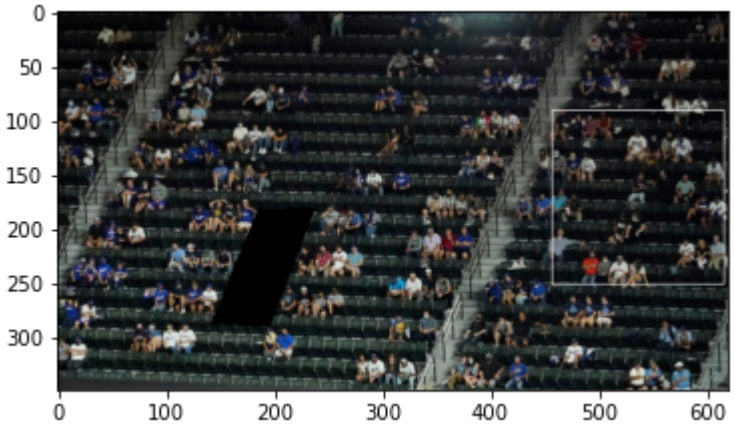
```
Would you like to select the region to be filled (0) or the sample texture re
gion (1)?
0 or 1: 1
Note: Code in Holefill.py forces the texture region to be rectangular
Please use your mouse to specify the region that you want for data/texture_re
gion_crowd.pkl
(Click to select each polygon vertex. Close the window to complete and save t
he polygon.)
```



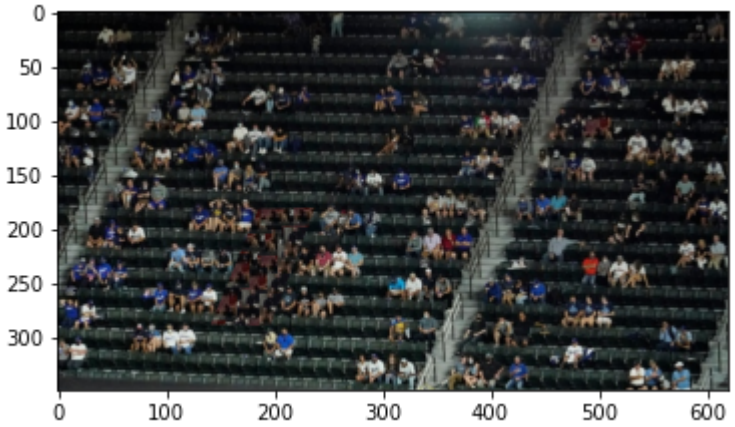
In [32]:
```
%matplotlib inline
texture_synthesis("data/crowd.jpg", randomPatchSD=0, patchL=15)
```

```
crowd
```






```
Are you happy with this choice of fillRegion and textureIm?
Yes or No: Yes
Number of pixels remaining =  5843
Number of pixels remaining =  1404
```



Question 7

The random patch standard deviation affects how we sample from the selected patch. The closer the standard deviation is to 0, the more likely the selected sample patch comes from the "best" texture patch. Hence, when randomPatchSD==0, the algorithm chooses the sample that has the smallest SSD compared with the texture image. While this may be "optimal", the results may not look the best when we want some randomization in our sampling (see "crowd.jpg" results above). In "crowd.jpg", you can see that some randomization is necessary- otherwise all the attendees in the fill-region are sampled from the same texture patch, with a person in a red shirt.

As PatchL (and therefore the size of the patch) increases, the less repetitive the synthesized texture is. Likewise, as the size of the patch decreases, the more repetitive the synthesized texture is. This occurs because when the patch size is small, the samples we generate from the patch will look very similar, creating a repetitive pattern. When the patch size is large, the samples generated are more varied, since they are more likely to come from different areas of the patch. If we are trying to fill texture into an image with a lot of identical repetitive patterns, a low patch size would be good. However, if we prefer more randomness in the texture, a larger patch size is needed.