Feature Detection

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February 12, 2018

1 Feature Detection

Given a target image with a feature and an input image, try to identify all locations of the target in the input.

This can be done using `matchTemplate` in openCV which uses convolution to find the response to the template in the target image. This approach can be used to find a single occurrence of the template (find the maximum response) or many (all responses above a threshold).

I also implemented the feature detection using `fftconvolve` from scipy.signal. This is the same approach used by openCV except implemented one step at a time. The response is normalized, and then either the maximum response can be found (to find a single occurrence) or find all responses above a specified threshold (to find many instances). The original image with the detected feature can then be plotted as well as the response colored by the magnitude oft the response.

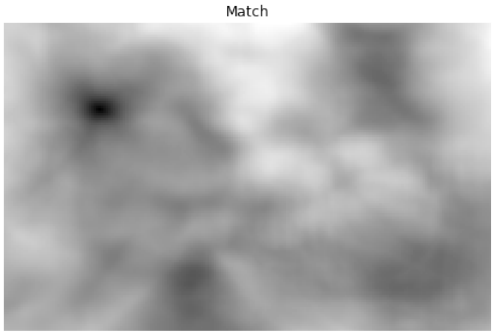
```
In [1]: import numpy as np

        import cv2
        from PIL import Image

        from scipy.signal import fftconvolve

        import os

        import matplotlib.pyplot as plt
        from matplotlib import cm
        %matplotlib inline
```

1.1 OpenCV Implementation

```
In [2]: def detect_features_opencv(target_image_path, template_path, number = 'one', threshold=0


            method = eval('cv2.TM_SQDIFF')

            if number == 'one':
                target = cv2.imread(target_image_path, 0)
                template = cv2.imread(template_path, 0)
                h, w = template.shape
```

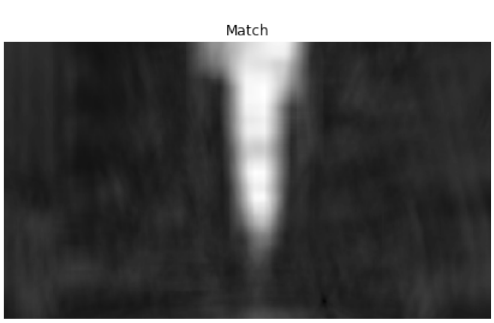
```
            res = cv2.matchTemplate(target, template, method)
            min_val, max_val, min_loc, max_loc = cv2.minMaxLoc(res)


            top_left = min_loc
            bottom_right = (top_left[0] + w, top_left[1] + h)
            cv2.rectangle(target, top_left, bottom_right, 255, 2)

            plt.figure(figsize=(16, 16))
            plt.subplot(121); plt.imshow(res, cmap='gray')
            plt.title('Match'); plt.axis('off')
            plt.subplot(122); plt.imshow(target, cmap='gray')
            plt.title('Detection'); plt.axis('off')
            plt.show();

        elif number == 'many':
            target_rgb = cv2.imread(target_image_path)
            target_gray = cv2.cvtColor(target_rgb, cv2.COLOR_BGR2GRAY)
            template = cv2.imread(template_path, 0)

            method = eval('cv2.TM_CCOEFF_NORMED')
            h , w = template.shape

            res = cv2.matchTemplate(target_gray, template, method)
            loc = np.where(res >= threshold)

            for point in zip(*loc[::-1]):
                cv2.rectangle(target_rgb, point, (point[0] + w, point[1] + h), (0, 0, 255),

            cv2.imwrite('result.png', target_rgb)
            result = plt.imread('result.png')
            plt.figure(figsize=(12, 12))
            plt.imshow(result); plt.axis('off');
            plt.title('Detection Results', size = 24);
            plt.show();

            os.remove('result.png')
        else:
            print('Enter Valid Number (one or many)')
```

In [3]:
```
detect_features_opencv('images/target.jpg', 'images/template.jpg')
```



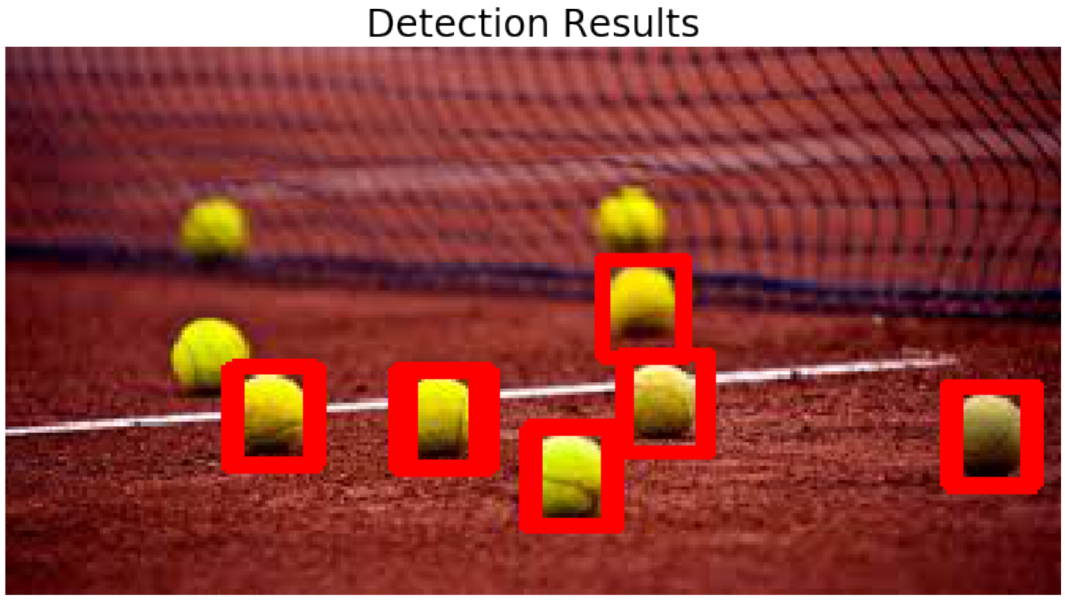
In [4]: detect_features_opencv('images/target.jpg', 'images/template.jpg', number = 'many', thre

In [5]: detect_features_opencv('images/target_street.jpg', 'images/template_human.jpg')




```
In [6]: detect_features_opencv('images/target_street.jpg', 'images/template_human.jpg',
                               number = 'many', threshold=0.75)
```


```
In [7]: detect_features_opencv('images/target_tennis.jpg', 'images/template_tennis.jpg',
                               number = 'many', threshold = 0.8)
```



1.2 Implementation by Hand

Using Fast Fourier Transform Convolution. Responses are normalized overall the three color channels.

```
In [8]: def _window_sum_2d(image, window_shape):
            window_sum = np.cumsum(image, axis=0)
            window_sum = (window_sum[window_shape[0]:-1] -
                          window_sum[:-window_shape[0] - 1])

            window_sum = np.cumsum(window_sum, axis=1)
            window_sum = (window_sum[:, window_shape[1]:-1] -
                          window_sum[:, :-window_shape[1] - 1])

            return window_sum

In [9]: def _window_sum_3d(image, window_shape):
            window_sum = _window_sum_2d(image, window_shape)

            window_sum = np.cumsum(window_sum, axis=2)
            window_sum = (window_sum[:, :, window_shape[2]:-1] -
                           window_sum[:, :, :-window_shape[2] - 1])

            return window_sum

In [10]: def detect_features(image_path, template_path, pad_input=True, mode='constant', constan
```

```
image = Image.open(image_path)
image = np.array(image, dtype=np.float64, copy=False)

orig_image = image.copy().astype(np.uint8)

template = Image.open(template_path)
template = np.array(template)

if image.ndim < template.ndim:
    raise ValueError("Dimensionaliy of template must be less than or equal"
                     " to the dimensionality of image.")
if np.any(np.less(image.shape, template.shape)):
    raise ValueError("Image must be larger than templtate")

image_shape = image.shape

pad_width = tuple((width, width) for width in template.shape)

if mode == 'constant':
    image = np.pad(image, pad_width=pad_width, mode=mode,
                   constant_values=constant_value)
else:
    image = np.pad(image, pad_width=pad_width, mode=mode)

if image.ndim == 2:
    image_window_sum = _window_sum_2d(image, template.shape)
    image_window_sum2 = _window_sum_2d(image ** 2, template.shape)

elif image.ndim == 3:
    image_window_sum = _window_sum_3d(image, template.shape)
    image_window_sum2 = _window_sum_3d(image ** 2, template.shape)

template_mean = template.mean()
template_volume = np.prod(template.shape)
template_ssd = np.sum((template - template_mean) ** 2)

if image.ndim == 2:
    xcorr = fftconvolve(image, template[::-1, ::-1],
                        mode='valid')[1:-1, 1:-1]
elif image.ndim == 3:
    xcorr = fftconvolve(image, template[::-1, ::-1, ::-1],
                        mode = 'valid')[1:-1, 1:-1, 1:-1]

# Normalization
numerator = xcorr - image_window_sum * template_mean
denominator = image_window_sum2
np.multiply(image_window_sum, image_window_sum, out=image_window_sum)
np.divide(image_window_sum, template_volume, out=image_window_sum)
```

```
        denominator = denominator - image_window_sum
        denominator = denominator * template_ssd
        np.maximum(denominator, 0, out=denominator)
        np.sqrt(denominator, out=denominator)

        response = np.zeros_like(xcorr, dtype=np.float64)

        mask = denominator > np.finfo(np.float64).eps

        response[mask] = numerator[mask] / denominator[mask]

        slices = []

        for i in range(template.ndim):
            if pad_input:
                d0 = (template.shape[i] - 1) // 2
                d1 = d0 + image_shape[i]
            else:
                d0 = template.shape[i] - 1
                d1 = d0 + image_shape[i] - template.shape[i] + 1
            slices.append(slice(d0, d1))

        return orig_image, template, response[slices]
```

1.3 Perform the Entire Process and Visualize Results

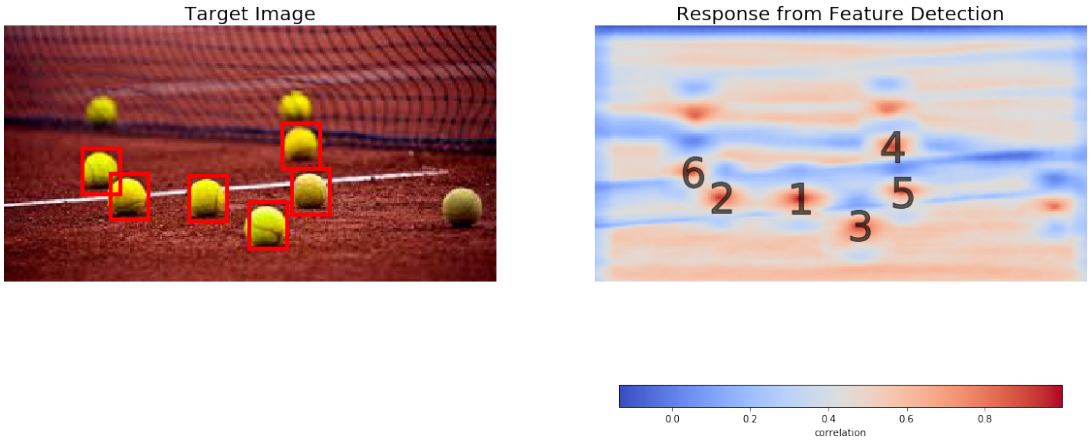
```
In [11]: def model(image_path, template_path, number = 'many', threshold = 0.8, analyze = False)

        image, template, response = detect_features(image_path, template_path,
                                                    pad_input=True)

        if not analyze:
            plt.figure(figsize=(2, 2))
            ax1 = plt.subplot(1, 1, 1)
            ax1.imshow(template)
            ax1.set_axis_off()
            ax1.set_title('Template', size = 20)
            plt.show()
            fig, _ = plt.subplots(1, 2, figsize=(20, 8))
            ax2 = plt.subplot(121, adjustable = 'box-forced')
            ax3 = plt.subplot(122, sharex = ax2, sharey = ax2, adjustable = 'box-forced')

        else:
            plt.figure(figsize=(10, 10))
            ax2 = plt.subplot(111)

        ax2.imshow(image)
```

```
ax2.set_axis_off()
ax2.set_title('Target Image', size = 20)

htemplate, wtemplate = template.shape[:2]

if number == 'many':
    detections = 0

    pos = np.array(np.where(response[:, :, :] > threshold))

    recorded_boxes = []


    positions = []
    for position in range(pos.shape[1]):
        x, y, z = pos[:, position]
        value = response[x, y, z]
        positions.append((x, y, z, value))

    positions = sorted(positions, key = lambda x: x[3], reverse = True)

    for entry in positions:

        y, x = entry[:2]

        record = False

        for box in recorded_boxes:

            left, right, bottom, top = box

            if (x > left) & (x < right) & (y > bottom) & (y < top):
                record = True

        if not record:
            rank = detections

            # left, right, bottom, top
            bounding_box = (x - wtemplate / 2, x + wtemplate / 2,
                            y - htemplate / 2, y + htemplate / 2)

            recorded_boxes.append(bounding_box)

            rect = plt.Rectangle((x - wtemplate / 2, y - htemplate / 2),
                                 wtemplate, htemplate, edgecolor='r', facecolor='none',
            ax2.add_patch(rect)

            if not analyze:
```

```
                        # circle = plt.Circle((x, y), radius = 6,  edgecolor='r', facecolor
                        ax3.plot(x,  y, marker = '$%d$' % (rank + 1), ms = 32, color = 'k',

                    detections += 1

                print('{} detections with threshold: {}\n'.format(detections, threshold))

            elif number == 'one':
                ij = np.unravel_index(np.argmax(response), response.shape)

                y, x = ij[:2]

                rect = plt.Rectangle((x - wtemplate / 2, y - htemplate / 2),
                                     wtemplate, htemplate, edgecolor='r', facecolor='none', lw
                ax2.add_patch(rect)
                circle = plt.Circle((x, y), radius = 6,  edgecolor='r', facecolor='none', lw =
                ax3.add_patch(circle)

            if not analyze:
                cax = ax3.imshow(response[:, :, 1], cmap=cm.coolwarm)
                fig.colorbar(cax, label = 'correlation', orientation = 'horizontal', shrink = 0
                ax3.set_axis_off()
                ax3.set_title('Response from Feature Detection', size = 20)
                ax3.autoscale(False)
                ax2.set_anchor('N')
                ax3.set_anchor('N')

            plt.show();
```

In [12]:
```
model(image_path = 'images/target_tennis.jpg', template_path = 'images/template_tennis.
```


```
6 detections with threshold: 0.85
```




```
In [13]: model(image_path = 'images/target_street.jpg', template_path = 'images/template_human.j
```


```
1 detections with threshold: 0.8
```