Session 3 - Solutions (PDF Version)

May 14, 2019

1 Session 3 - Solutions

1.1 Exercise 1

```
In [2]: def circle_area(r):
            '''Return circle area'''
            return pi * r**2 / 4


        # Import pi from the math library
        from math import pi

        # Test function with input with r=20, save returned value
        A20 = circle_area(r=20)

        # Print the result
        print(A20)
```

```
314.1592653589793
```

- **Note**: Calling the funtion as `circle_area(20)` and `circle_area(r=20)` is the same.

1.2 Exercise 2

```
In [3]: def circle_areas(radii):
            # Use list comprehension to return a list of radii
            return [circle_area(r) for r in radii]


        # Define list of radii
        list_of_radii = [10, 12, 16, 20, 25, 32]

        # Call function with input list
        list_of_areas = circle_areas(list_of_radii)

        # Print result with two decimals
        print([round(d, 2) for d in list_of_areas])
```

```
[78.54, 113.1, 201.06, 314.16, 490.87, 804.25]
```

- **Note 1:** Call to function `circle_area` defined in Exercise instead of defining the expression `pi * r**2 / 4` again. The concept of functions calling other functions can be used to make modular programs that are easy to follow and maintain. Each function only needs to do a small thing in itself.
- **Note 2:** The input parameter when the function was *defined* was a list called `radii`, but the when the function was *called*, the input list was called `list_of_radii`. Thus, the input parameters passed into a function do not need to have the same name as when the function is defined.

1.3 Exercise 3

```
In [4]: def is_pile_long(pile_lengths):

            # Create True or False value by list comprehension with if/else
            return [True if length >= 5 else False for length in pile_lengths]


        # Define a list of some pile lengths to test
        piles = [4.51, 6.12, 4.15, 7.31, 5.01, 4.99, 5.00]

        # Call function
        print(is_pile_long(piles))
```

```
[False, True, False, True, True, False, True]
```

- **Note:** The built-in boolean values `True` and `False` *must* be capitalized to be recognized by Python. If for example `true` is used, Python will assume that it is a variable that you have named `true` and give an error if it is not defined. All editors will highlight the special words recognized by Python, so if the editor does not highlight, it's a sign that something is wrong.

1.4 Exercise 4

```
In [5]: # Import sqrt from the math library
        from math import sqrt


        def dist_point_to_line(x, y, x1, y1, x2, y2):
            '''Return distance between a point and a line defined by two points.

            Args:
                x  : x-coordinate of point
                y  : y-coordinate of point
                x1 : x-coordinate of point 1 defining the line
                y1 : y-coordinate of point 1 defining the line
```

```
            x2 : x-coordinate of point 2 defining the line
            y2 : y-coordinate of point 2 defining the line

        Returns:
               The distance between the point and the line
        '''
        return abs((y2-y1)*x-(x2-x1)*y+x2*y1-x1*y2)/sqrt((x2-x1)**2 + (y2-y1)**2)


    # Call the function with the two test cases
    print(dist_point_to_line(2, 1, 5, 5, 1, 6))
    print(dist_point_to_line(1.4, 5.2, 10.1, 2.24, 34.142, 13.51))
```

```
4.608176875690327
6.3728037317960675
```

- **Note:** `abs()` used to get the numerical value.

1.5 Exercise 5

```
In [7]: # Two points defining the line
        x1, y1, x2, y2 = 2, 3, 8, 7

        # Define points for distance to line calculation
        x_coords = [4.1, 22.2, 7.7, 62.2, 7.8, 1.1]
        y_coords = [0.3, 51.2, 3.5, 12.6, 2.7, 9.8]

        # Call function dist_point_to_line for all (x, y) points
        distances = [dist_point_to_line(x_coords[i], y_coords[i], x1, y1, x2, y2) \
                     for i in range(len(x_coords))]

        # Note: the '\' in the line above is just a continuation character

        # Print new list
        print([round(d, 2) for d in distances])
```

```
[3.41, 28.9, 2.75, 25.41, 3.47, 6.16]
```

A way that I like better than the above is using the `zip` function, which takes the two coordinate lists and puts them side by side, almost like a zipper. It is often more clean and expressive than using a loop counter `i` over the length of one of the lists.

```
In [8]: # Solution using zip
        distances_zip = [dist_point_to_line(x, y, x1, y1, x2, y2) \
                         for x, y in zip(x_coords, y_coords)]

        # Note: the '\' in the line above is just a continuation character
```

```
        # Print results with two decimals
        print([round(d, 2) for d in distances_zip])
```

```
[3.41, 28.9, 2.75, 25.41, 3.47, 6.16]
```

1.6 Exercise 6

```
In [8]: def polygon_area(xv, yv, signed=False):
            ''' Return the area of a non-self-intersecting polygon given
            the coordinates of its vertices'''

            # Perform shoelace multiplication
            a1 = [xv[i] * yv[i+1] for i in range(len(xv)-1)]
            a2 = [yv[i] * xv[i+1] for i in range(len(yv)-1)]

            # Check i area should be signed and return area
            if signed:          # <--- Same as "if signed == True:"
                return 1/2 * ( sum(a1) - sum(a2) )
            else:
                return 1/2 * abs( sum(a1) - sum(a2) )


        # Define the polygon vertices to test
        x = [3, 4, 7, 8, 8.5, 3]
        y = [5, 3, 0, 1, 3, 5]

        # Calculate area by calling the function
        A = polygon_area(x, y)

        # Print the area
        print(A)
```

```
12.0
```

1.7 Exercise 7

```
In [9]: def polygon_centroid(x, y):

            # Initialize empty lists for holding summation terms
            cx, cy = [], []

            # Loop over vertices and put the summation terms in the lists
            for i in range(len(x)-1):

                # Compute and append summation terms to each list
```

```
            cx.append((x[i] + x[i+1]) * (x[i] * y[i+1] - x[i+1] * y[i]))
            cy.append((y[i] + y[i+1]) * (x[i] * y[i+1] - x[i+1] * y[i]))

        # Calculate the signed polygon area by calling already defined function
        A = polygon_area(x, y, signed=True)

        # Sum summation terms and divide by 6A to get coordinates
        Cx = sum(cx) / (6*A)
        Cy = sum(cy) / (6*A)

        return Cx, Cy


    # Define lists of vertex coordinates for testing
    x = [3, 4, 7, 8, 8.5, 3]
    y = [5, 3, 0, 1, 3, 5]

    # Compute centroid by calling function, store in two variables
    cx, cy = polygon_centroid(x, y)

    # Print result
    print(cx, cy)
```

```
6.083333333333333 2.5833333333333335
```

```
In [10]: # Print result as text with formatted decimals
         print(f'Polygon centroid is at (Cx, Cy) = ({cx:.1f}, {cy:.1f})')
```

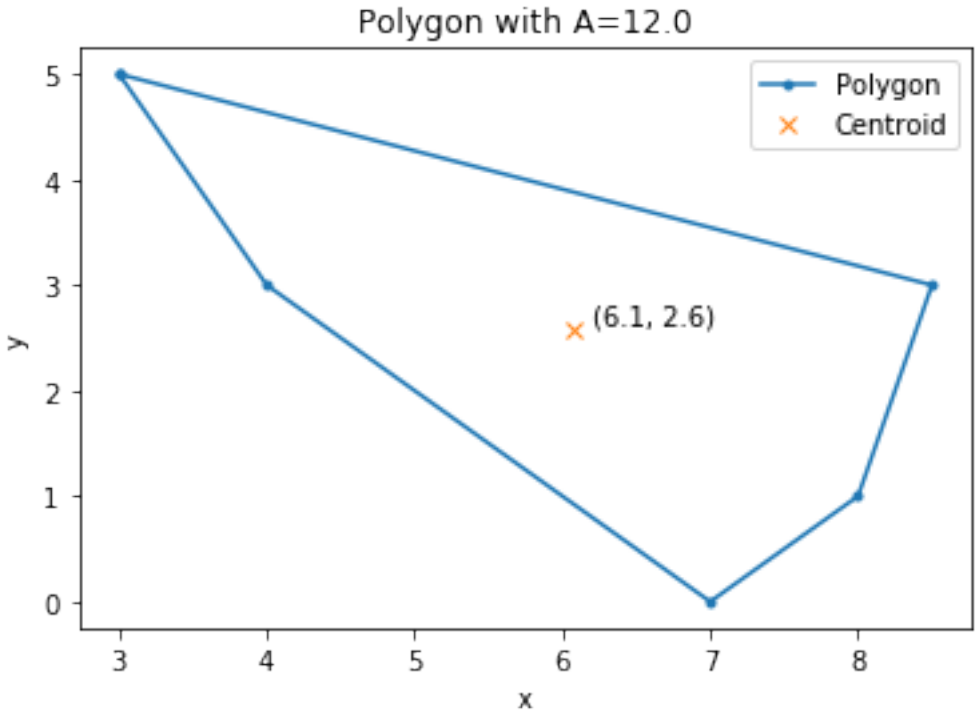
```
Polygon centroid is at (Cx, Cy) = (6.1, 2.6)
```

1.8 Appetizer for next time - Plotting

1.8.1 Plotting the solution for the polygon centroid exercise:

```
In [13]: import matplotlib.pyplot as plt

         # Plot polygon from exercises with centroid and area
         plt.plot(x, y, '.-', label='Polygon')
         plt.plot(cx, cy, 'x', label='Centroid')

         # Plot coordinates of centroid as text
         plt.annotate(f'({cx:.1f}, {cy:.1f})', xy=(cx, cy),
                      xytext=(cx, cy), textcoords='offset points')

         # Set labels, titles and legend
         plt.xlabel('x')
         plt.ylabel('y')
```

```
plt.title(f'Polygon with A={A}')
plt.legend()
plt.show()
```

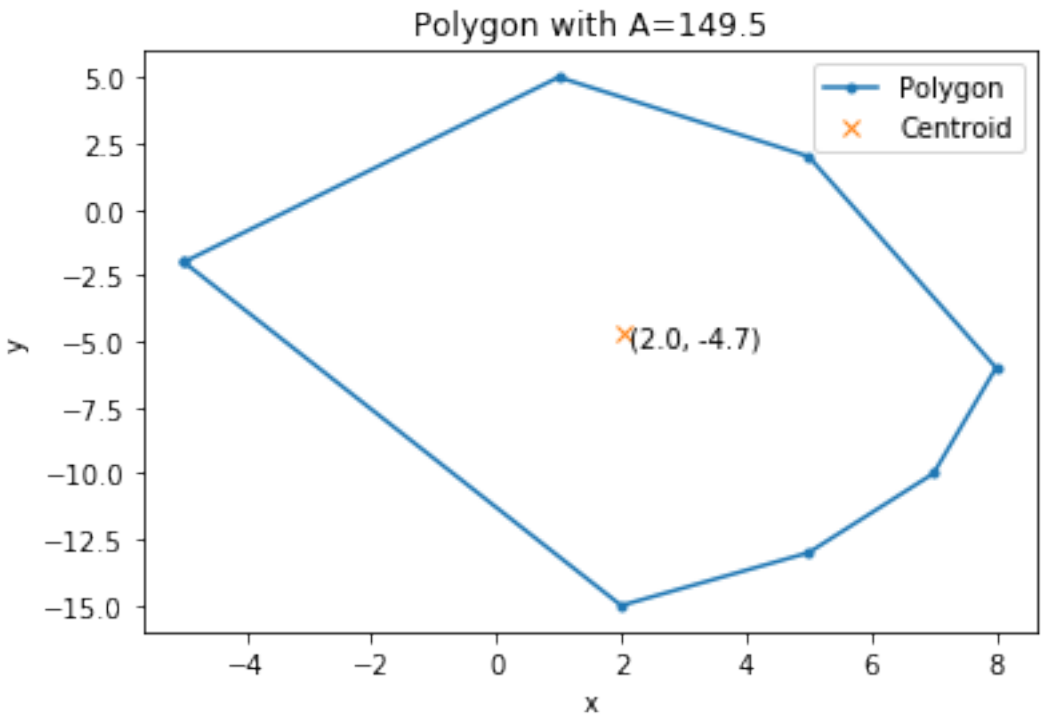


1.8.2 Function for plotting an arbitrary polygon

The plotting code above could be turned into a function to plot an arbitrary polygon together with its center of gravity and put its area in the title:

```
In [12]: def plot_polygon(xv, yv, plot_centroid=True):
             '''Plot the polygon with the specified vertex coordinates.

             The plot is created with legend and the computed area of the
             polygon shown in the title. The plot shows the centroid of
             the polygon by default, but this can be turned off by setting
             plot_centroid=False.

             Args:
                 xv (list)           : x-coordinates of polygon vertices
                 yv (list)           : y-coordinates of polygon vertices
                 plot_centroid (bool) : Plot centroid of polygon (Cx, Cy).
                                        Defaults to plotting the centroid.
             '''
```

```
    # Compute area of polygon
    A = polygon_area(xv, yv)

    # Compute polygon centroid
    cx, cy = polygon_centroid(xv, yv)

    # Plot the polygon
    plt.plot(xv, yv, '.-', label='Polygon')

    # Plot the centroid with coordinates if that was chosen
    if plot_centroid:   # <- Eqiuvalent to: if plot_centroid == True:
        plt.plot(cx, cy, 'x', label='Centroid')
        plt.annotate(f'({cx:.1f}, {cy:.1f})', xy=(cx, cy),
                     xytext=(cx, cy), textcoords='offset points')

    # Set labels, titles and legend
    plt.xlabel('x')
    plt.ylabel('y')
    plt.title(f'Polygon with A={A}')
    plt.legend()
    plt.show()


# Define vertices of some random polygon
x_polygon = [-5, 2, 5, 7, 8, 5, 1, -5]
y_polygon = [-2, -15, -13, -10, -6, 2, 5, -2]

# Call function to plot polygon with area and centroid shown
plot_polygon(x_polygon, y_polygon)
```



- **Note 1:** Optional input parameter `plot_centroid` has `True` as default argument. `True` is immutable.
- **Note 2:** The area of the polygon is actually calculated both in the `polygon_area()` function and in the `polygon_centroid()` function, which is maybe not so clean. A way to overcome this could be to have `polygon_centroid` return the area. Thereby running the `polygon_area`function alone would not be necessary.