Contents

1 The distance file

These points were hand measured along the channel of the microreactor. We read them in, and compute the distance along the lines. The first point corresponds to the y-junction, and represents d = 0.

```
import numpy as np
import matplotlib.pyplot as plt
import pycse.orgmode as org

data = np.loadtxt('05MEA-5-2-16-distance.txt')
x, y = data.T

# These distances are in pixels. We need a conversion to get it in microns.
distances = [np.sqrt((x[i - 1] - x[i]) ** 2 + (y[i - 1] - y[i]) ** 2)
             for i in range(1, len(x))]

cumulative_distance = np.cumsum(distances)

print(len(x))
```

182

Now, we plot the data.

```
plt.figure()
plt.plot(x, y)
plt.xlabel('x-coordinate')
plt.ylabel('y-coordinate')
plt.gca().invert_yaxis()
org.figure(plt.savefig('distance.png'), caption='The points used to compute the distances.')

plt.figure()
plt.plot([i for i in range(1, len(x))], cumulative_distance)
plt.xlabel('Point index')
plt.ylabel('Distance to point along the channel.')
org.figure(plt.savefig('cumulative-distance.png'))
```

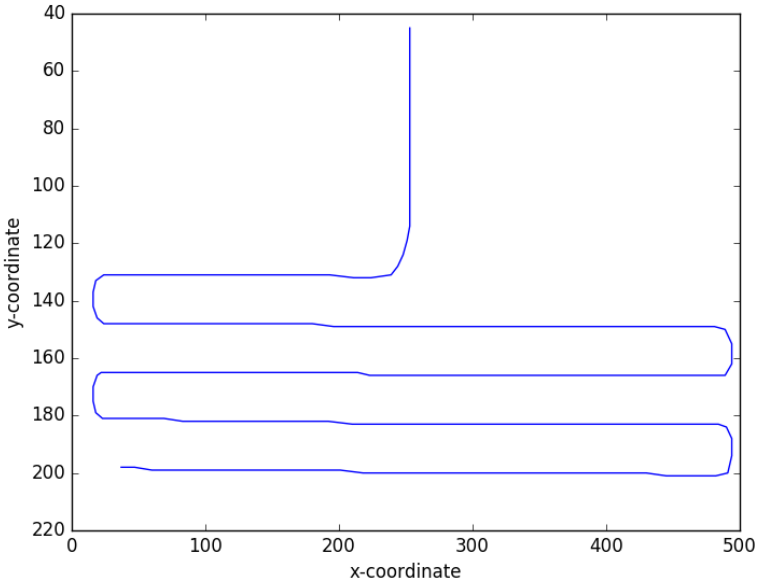


Figure 1: The points used to compute the distances.

2 Frame data

This is data that comes from image analysis. There are 4 columns:

1. The index of the bubble
2. The area of the bubble in pixels
3. The x-coordinate of the center of mass of the bubble.
4. The y-coordinate of the center of mass of the bubble.

We plot the COMs and the channel distance data here.

```
import numpy as np
import matplotlib.pyplot as plt
import pycse.orgmode as org
data = np.loadtxt('frame-14.txt', skiprows=1)

indices, areas, x_com, y_com = data.T
plt.figure()
plt.scatter(x_com, y_com, s=areas)
plt.gca().invert_yaxis()
```

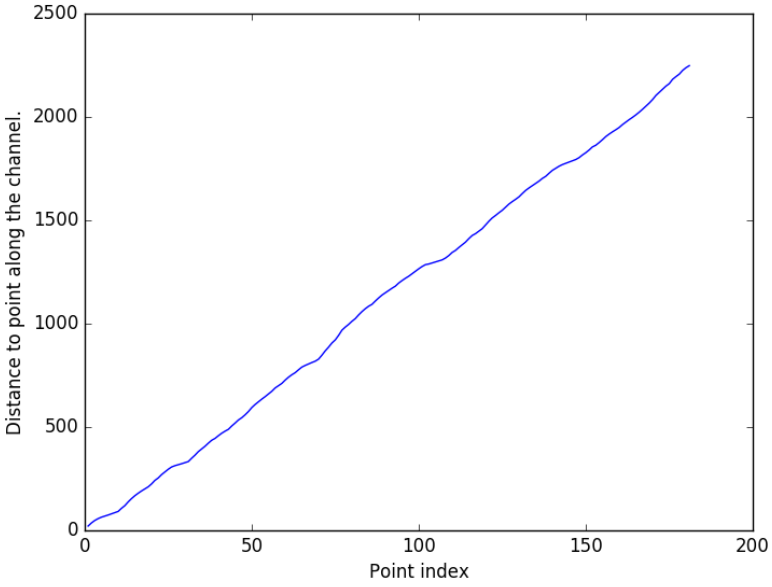


Figure 2: The points used to compute the distances.

```
plt.xlabel('x-coordinate')
plt.ylabel('y-coordinate')
plt.plot(x, y, 'b.')
plt.xlim([0, 500])
org.figure(plt.savefig('bubble-x-y.png'), caption='Location of the bubble centers of mass.')

microns2pixels = 2000/85.259
hydraulic_diameter = 121.0  # microns
AREA = 15270  # What is this

# the areas in um^2
areas_um2 = areas * (microns2pixels ** 2)
length_noends = (areas_um2 - np.pi * hydraulic_diameter ** 2 / 4) / hydraulic_diameter

# um^3
volumes = length_noends * AREA + np.pi * hydraulic_diameter ** 3 / 6
```

3 Calculating the distance to each bubble COM

The principle idea is to consider the data that defines the distance along the channel as a list of segments. We want to find the segment that a particular

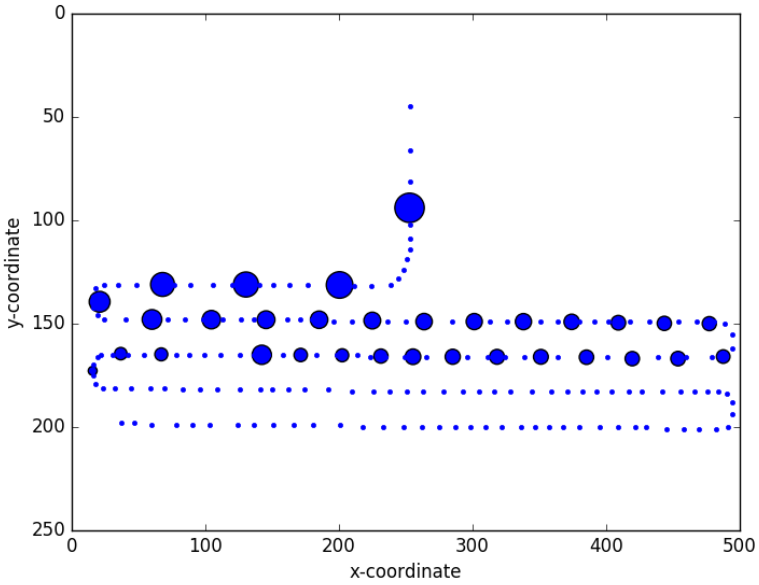


Figure 3: Location of the bubble centers of mass.

COM is closest to, and where the intersection is between the points. Then, we just sum the distances up to the point closest to the y-junction, and then add the distance to the COM.

We have points in two lists: x, y for the distances along the channel. We need to create a new list of segments. This list will have one less element in it than the list of points.

```
# List of segments, a list of (P1, P2) pairs that define a segment

segments = [[(x[i - 1], y[i - 1]), (x[i], y[i])] for i in range(1, len(x))]
print(len(segments))
print(len(x))
```

```
181
182
```

The distance from a point to https://en.wikipedia.org/wiki/Distance_from_a_point_to_a_line#Line_defined_by_two_points

First, we define a function that returns the distance from a point P0 to a segment defined by two points P1 and P2. The points P1 and P2 will be

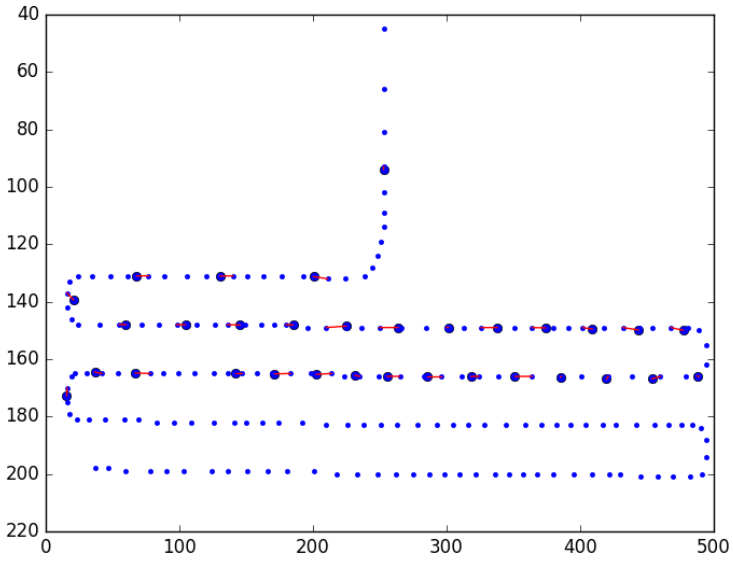
from the channel distance set.

```
def distance_to_segment(P1, P2, P0):
    """Return distance of P0 to the segement defined by P1 and P2.

    https://en.wikipedia.org/wiki/Distance_from_a_point_to_a_line#Line_defined_by_two_points
    """
    x1, y1 = P1
    x2, y2 = P2
    x0, y0 = P0

    # vertical case
    if x1 == x2:
        #print('vertical segment')
        a = 1.0
        b = 0.0
        c = -x0
        d = np.abs(a * x0 + c) / np.abs(a)
        x = x1
        y = y0
    # horizontal case
    elif y1 == y2:
        #print('horizontal segment')
        a = 0.0
        b = -1.0
        c = y1
        d = np.abs(b * y0 + c) / np.abs(b)
        x = x0
        y = y1
    # The general case
    else:
        a = (y2 - y1) / (x2 - x1)
        b = -1.0
        c = y2 - a * x2
        d = np.abs(a * x0 + b * y0 + c) / np.sqrt(a ** 2 + b ** 2)

        # point of intersection
        x = (b * (b * x0 - a * y0) - a * c) / np.sqrt(a ** 2 + b ** 2)
        y = (a * (-b * x0 + a * y0) - b * c) / np.sqrt(a ** 2 + b ** 2)

    # determine if (x, y) is between P1 and P2
    segment_length = np.sqrt((x1 - x2) ** 2 + (y1 - y2) ** 2)

    # distance of intersection to segment points
    d1 = np.sqrt((x1 - x) ** 2 + (y1 - y) ** 2)
    d2 = np.sqrt((x2 - x) ** 2 + (y2 - y) ** 2)

    # if d1 + d2 == segment length, the intersection is between the segments.
    # We use a tolerance for the comparison. The tolerance is one pixel.
    if np.abs(d1 + d2 - segment_length) < 1:
        return d
    else:
        # return a large number since the intersection is not between the points.
        return 1e10
```

Now we get the index to the shortest distance from each point to the

segments, and plot them. This will make sure we

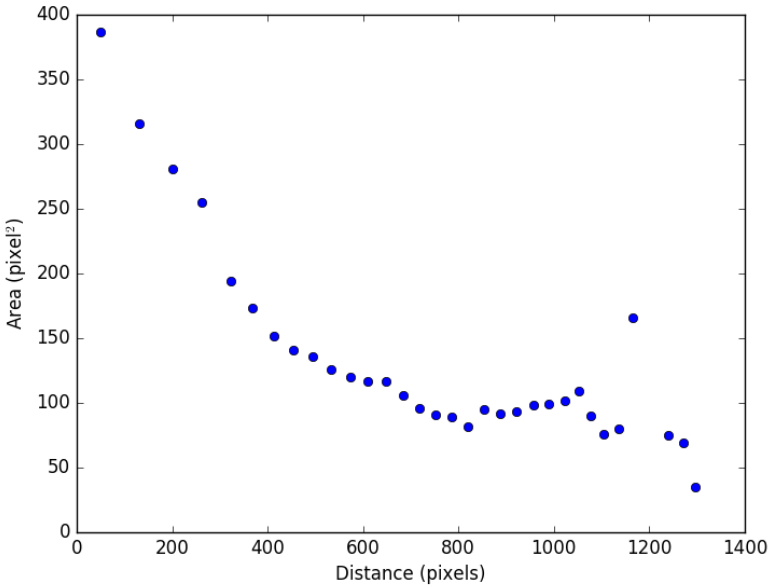
```
inds = [np.argmin([distance_to_segment(seg[0], seg[1],
                                       com) for seg in segments])
        for com in zip(xs, ys)]


plt.figure()
plt.gca().invert_yaxis()
plt.plot(xs, ys, 'bo')
plt.plot(x, y, 'b.')

# now lines connecting them.

channel_dists = []
for i, ind in enumerate(inds):
    P1, P2 = segments[ind]
    #print(P1, xs[i], ys[i])
    d1 = np.sum(distances[0: ind])
    d2 = np.sqrt((xs[i] - P1[0]) ** 2 + (ys[i] - P1[1]) ** 2)
    channel_dists += [d1 + d2]
    plt.plot([xs[i], P1[0]], [ys[i], P1[1]], 'r-')

org.figure(plt.savefig('closest-dots.png'))

print(len(channel_dists))
```



32

Finally, we can plot the areas vs the distance.

```
plt.figure()
plt.plot(channel_dists, areas, 'bo')
plt.xlabel('Distance (pixels)')
plt.ylabel('Area (pixel$^2$)')
org.figure(plt.savefig('area-vs-dist.png'))
```



It looks like there is one outlier, point 20.

```
data = [(i, *tup) for i, tup in enumerate(zip(channel_dists, areas, xs, ys))]

org.table([['i', 'distance', 'area', 'x', 'y'], None] + data)
```

i	distance	area	x	y
0	48.9602671503	387.0	252.847	93.948
1	322.995857341	194.0	20.875	139.401
2	262.794010213	255.0	67.971	131.025
3	200.340116802	281.0	130.425	131.052
4	130.287574005	316.0	200.475	131.269
5	369.019013956	173.0	60.072	147.957
6	413.454047525	152.0	104.507	148.053
7	454.376122061	141.0	145.429	148.074
8	494.09163654	136.0	185.144	148.091
9	533.937713054	126.0	224.951	148.491
10	572.68705739	120.0	263.709	148.987
11	610.230227332	117.0	301.252	148.979
12	647.047054582	117.0	338.069	149.009
13	683.15767843	106.0	374.179	149.113
14	718.098861293	96.0	409.1	149.544
15	752.532697781	91.0	443.524	149.841
16	786.211883204	89.0	477.182	149.977
17	819.925503504	82.0	487.592	165.908
18	1270.89043209	69.0	36.703	164.5
19	1240.55708053	75.0	67.014	164.838
20	1165.33213826	166.0	142.238	165.049
21	1136.20278988	80.0	171.368	165.145
22	1105.14349498	76.0	202.43	165.289
23	1076.1402768	90.0	231.389	165.673
24	1052.12050623	109.0	255.394	165.99
25	1022.36750102	102.0	285.147	166.0
26	989.218585262	99.0	318.296	166.031
27	956.392543305	98.0	351.122	166.033
28	922.280092299	93.0	385.267	166.221
29	888.243889933	92.0	419.535	166.919
30	853.795031256	95.0	453.784	166.898
31	1296.56533113	35.0	15.671	172.814

This is for sure wrong.

```
print(xs[4], ys[4], areas[4])

print(np.argmin([distance_to_segment(seg[0], seg[1], [xs[4], ys[4]]) for seg in segments]))
print(segments[44])
```

```
200.475 131.269 316.0
```

```
12
[(196.0, 149.0), (210.0, 149.0)]
```