import matplotlib.pyplot as plt

import math

# point cloud points sampled at equal intervals

# starts at wiki gate 24.5 and ordered by rising elevation

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# distance values in clockwise order from wiki gate 24.5 and rising elevation

el29 = [0.239, 0.234, 0.229, 0.226, 0.197, 0.197, 0.212, 0.199, 0.187, 0.19, 0.169, 0.177, 0.167, 0.187, 0.177, 0.197,

0.215, 0.222, 0.222, 0.227, 0.241, 0.257, 0.268, 0.28250000000000003, 0.29700000000000004, 0.3115, 0.326,

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0.307, 0.3015, 0.296, 0.2905, 0.285, 0.27599999999999997, 0.267, 0.258, 0.249, 0.244]

el32 = [0.1845, 0.17425000000000002, 0.164, 0.152, 0.205, 0.162, 0.178, 0.155, 0.162, 0.172, 0.142, 0.135, 0.143, 0.143,

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0.205, 0.19474999999999998]

el35 = [0.179, 0.17400000000000002, 0.169, 0.157, 0.178, 0.169, 0.169, 0.163, 0.179, 0.151, 0.131, 0.159, 0.146, 0.142,

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el38 = [0.203, 0.1945, 0.186, 0.197, 0.201, 0.201, 0.19, 0.208, 0.186, 0.175, 0.156, 0.156, 0.166, 0.176, 0.166, 0.171,

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0.145, 0.127, 0.137, 0.141, 0.156, 0.174, 0.197, 0.21275, 0.2285, 0.24425000000000002, 0.26, 0.273,

0.28600000000000003, 0.299, 0.312, 0.322, 0.33199999999999996, 0.34199999999999997, 0.352, 0.35375, 0.3555,

0.35724999999999996, 0.359, 0.35175, 0.34450000000000003, 0.33725, 0.33, 0.32175, 0.3135, 0.30525, 0.297,

0.2935, 0.29, 0.2865, 0.283, 0.28925, 0.2955, 0.30174999999999996, 0.308, 0.31025, 0.3125, 0.31475, 0.317,

0.29775, 0.27849999999999997, 0.25925, 0.24, 0.24925, 0.2585, 0.26775000000000004, 0.277, 0.29200000000000004,

0.30700000000000005, 0.322, 0.337, 0.34025, 0.3435, 0.34675, 0.35, 0.34299999999999997, 0.33599999999999997,

0.329, 0.322, 0.31075, 0.2995, 0.28825, 0.277, 0.26475000000000004, 0.2525, 0.24025000000000002, 0.228, 0.21425,

0.2005, 0.18675, 0.173, 0.16899999999999998, 0.16499999999999998, 0.161, 0.157, 0.157]

el47 = [0.2025, 0.20275, 0.203, 0.196, 0.188, 0.176, 0.17, 0.162, 0.152, 0.146, 0.139, 0.138, 0.131, 0.131, 0.132,

0.139, 0.151, 0.157, 0.169, 0.181, 0.196, 0.212, 0.234, 0.2515, 0.269, 0.2865, 0.304, 0.31825, 0.3325, 0.34675,

0.361, 0.3705, 0.38, 0.3895, 0.399, 0.4015, 0.404, 0.4065, 0.409, 0.40075, 0.39249999999999996, 0.38425, 0.376,

0.36675, 0.35750000000000004, 0.34825, 0.339, 0.33575, 0.3325, 0.32925000000000004, 0.326, 0.33475, 0.3435,

0.35225, 0.361, 0.351, 0.34099999999999997, 0.331, 0.321, 0.309, 0.29700000000000004, 0.28500000000000003,

0.273, 0.28500000000000003, 0.29700000000000004, 0.309, 0.321, 0.3355, 0.35, 0.3645, 0.379, 0.3845, 0.39,

0.3955, 0.401, 0.39225, 0.3835, 0.37475, 0.366, 0.35475, 0.3435, 0.33225, 0.321, 0.30825, 0.2955, 0.28275, 0.27,

0.25625000000000003, 0.2425, 0.22875, 0.215, 0.21175, 0.20850000000000002, 0.20525000000000002, 0.202, 0.20225]

el50 = [0.216, 0.217, 0.218, 0.209, 0.201, 0.194, 0.184, 0.176, 0.167, 0.16, 0.166, 0.149, 0.14, 0.142, 0.144, 0.146,

0.154, 0.169, 0.174, 0.188, 0.204, 0.222, 0.244, 0.2625, 0.281, 0.2995, 0.318, 0.332, 0.346, 0.36, 0.374, 0.385,

0.396, 0.407, 0.418, 0.4195, 0.421, 0.4225, 0.424, 0.4155, 0.40700000000000003, 0.3985, 0.39, 0.38025, 0.3705,

0.36075, 0.351, 0.34675, 0.3425, 0.33825, 0.334, 0.3385, 0.34299999999999997, 0.3475, 0.352, 0.34325, 0.3345,

0.32575, 0.317, 0.30775, 0.2985, 0.28925, 0.28, 0.29350000000000004, 0.30700000000000005, 0.3205, 0.334,

0.34900000000000003, 0.364, 0.379, 0.394, 0.399, 0.404, 0.409, 0.414, 0.40625, 0.39849999999999997, 0.39075,

0.383, 0.37075, 0.35850000000000004, 0.34625, 0.334, 0.32025000000000003, 0.3065, 0.29275, 0.279,

0.26775000000000004, 0.2565, 0.24525000000000002, 0.234, 0.229, 0.224, 0.219, 0.214, 0.215]

el52 = [0.2375, 0.23875, 0.24, 0.231, 0.222, 0.212, 0.204, 0.195, 0.188, 0.177, 0.168, 0.159, 0.156, 0.158, 0.158,

0.161, 0.168, 0.177, 0.194, 0.202, 0.219, 0.235, 0.259, 0.27825, 0.2975, 0.31675000000000003, 0.336, 0.35025,

0.36450000000000005, 0.37875000000000003, 0.393, 0.4035, 0.41400000000000003, 0.4245, 0.435,

0.43674999999999997, 0.4385, 0.44025000000000003, 0.442, 0.4335, 0.425, 0.4165, 0.408, 0.39899999999999997,

0.39, 0.381, 0.372, 0.367, 0.362, 0.357, 0.352, 0.35724999999999996, 0.3625, 0.36775, 0.373, 0.36175,

0.35050000000000003, 0.33925, 0.328, 0.319, 0.31, 0.301, 0.292, 0.3075, 0.32299999999999995,

0.33849999999999997, 0.354, 0.36924999999999997, 0.38449999999999995, 0.39975, 0.415, 0.4205, 0.426, 0.4315,

0.437, 0.42825, 0.4195, 0.41075, 0.402, 0.389, 0.376, 0.363, 0.35, 0.33549999999999996, 0.32099999999999995,

0.3065, 0.292, 0.27875, 0.26549999999999996, 0.25225, 0.239, 0.238, 0.237, 0.236, 0.235, 0.23625]

el56 = [0.255, 0.257, 0.259, 0.251, 0.24, 0.231, 0.222, 0.212, 0.204, 0.192, 0.179, 0.173, 0.17, 0.17, 0.17, 0.171,

0.178, 0.187, 0.198, 0.211, 0.237, 0.248, 0.272, 0.29175, 0.3115, 0.33125, 0.351, 0.36574999999999996,

0.38049999999999995, 0.39525, 0.41, 0.42074999999999996, 0.4315, 0.44225000000000003, 0.453, 0.455, 0.457,

0.459, 0.461, 0.4525, 0.444, 0.4355, 0.427, 0.41625, 0.40549999999999997, 0.39475, 0.384, 0.38075000000000003,

0.3775, 0.37424999999999997, 0.371, 0.37424999999999997, 0.3775, 0.38075000000000003, 0.384, 0.3735, 0.363,

0.35250000000000004, 0.342, 0.33175, 0.3215, 0.31125, 0.301, 0.31825, 0.3355, 0.35275, 0.37, 0.38575,

0.40149999999999997, 0.41725, 0.433, 0.439, 0.445, 0.451, 0.457, 0.4475, 0.438, 0.4285, 0.419, 0.40525,

0.39149999999999996, 0.37775, 0.364, 0.34875, 0.3335, 0.31825, 0.303, 0.29025, 0.27749999999999997, 0.26475,

0.252, 0.25175000000000003, 0.2515, 0.25125, 0.251, 0.253]

new = []

for p in el29:

new += [p \* .0254]

el29 = list(new)

new = []

for p in el32:

new += [p \* .0254]

el32 = list(new)

new = []

for p in el35:

new += [p \* .0254]

el35 = list(new)

new = []

for p in el38:

new += [p \* .0254]

el38 = list(new)

new = []

for p in el41:

new += [p \* .0254]

el41 = list(new)

new = []

for p in el44:

new += [p \* .0254]

el44 = list(new)

new = []

for p in el47:

new += [p \* .0254]

el47 = list(new)

new = []

for p in el50:

new += [p \* .0254]

el50 = list(new)

new = []

for p in el52:

new += [p \* .0254]

el52 = list(new)

new = []

for p in el56:

new += [p \* .0254]

el56 = list(new)

new = []

points = points29 + points32 + points35 + points38 + points41 + points44 + points47 + points50 + points52 + points56

dist = el29 + el32 + el35 + el38 + el41 + el44 + el47 + el50 + el52 + el56

# starting parameters

xc = 10000.000615397612

yc = 10000.00040379931

zc = 151.82316465831497

rc = 3.3240036718929082

alpha = 0.0007 # learning rate

mse = 00

while mse > 0.0004:

x\_change = 0

y\_change = 0

z\_change = 0

r\_change = 0

mse = 0

for i in range(0, len(points)):

mse += (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \*\* 2

x\_change += 2 \* (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \* (

(1 / 2) \* (1 / math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)))) \* (

2 \* (xc - points[i][0]))

y\_change += 2 \* (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \* (

(1 / 2) \* (1 / math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)))) \* (

2 \* (yc - points[i][1]))

z\_change += 2 \* (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \* (

-0.5 \* (1 / (math.sqrt(rc \*\* 2 - (zc - points[i][2]))))) \* (-2 \* (zc - points[i][2]))

r\_change += 2 \* (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \* (

-0.5 \* (1 / (math.sqrt(rc \*\* 2 - (zc - points[i][2]))))) \* (2 \* rc)

mse = math.sqrt(mse / len(points))

print(“rmse:”, mse)

rmse = (1 / mse) \* 0.5

x\_change = (x\_change / len(points)) \* rmse

y\_change = (y\_change / len(points)) \* rmse

z\_change = (z\_change / len(points)) \* rmse

r\_change = (r\_change / len(points)) \* rmse

xc = xc - alpha \* x\_change

yc = yc - alpha \* y\_change

zc = zc - alpha \* z\_change

rc = rc - alpha \* r\_change

print(“xc:”, xc, “yc:”, yc, “zc:”, zc, “rc:”, rc)

# xc = 10000.000615212366

# yc = 10000.000403627007

# zc = 151.82313134652927

# rc = 3.3244697186758834

xc = 10000.000615397626

yc = 10000.000403799317

zc = 151.82316375798794

rc = 3.3240036131826427

# xc = 10000.0007

# yc = 10000.0005

# zc = 151.826

# rc = 3.324

for i in range(0, len(points)):

mse += (math.sqrt(((xc - points[i][0]) \*\* 2) + ((yc - points[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points[i][2]) \*\* 2)) - dist[i]) \*\* 2

mse = math.sqrt(mse / len(points))

print(mse)

y = [1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3.5, 3.75, 4.0, 4.25, 4.5, 4.75, 5.0, 5.25, 5.5, 5.75, 6.0,

6.25, 6.5, 6.75, 7.0, 7.25, 7.5, 7.75, 8.0, 8.25, 8.5, 8.75, 9.0, 9.25, 9.5, 9.75, 10.0, 10.25, 10.5, 10.75, 11.0,

11.25, 11.5, 11.75, 12.0, 12.25, 12.5, 12.75, 13.0, 13.25, 13.5, 13.75, 14.0, 14.25, 14.5, 14.75, 15.0, 15.25,

15.5, 15.75, 16.0, 16.25, 16.5, 16.75, 17.0, 17.25, 17.5, 17.75, 18.0, 18.25, 18.5, 18.75, 19.0, 19.25, 19.5,

19.75, 20.0, 20.25, 20.5, 20.75, 21.0, 21.25, 21.5, 21.75, 22.0, 22.25, 22.5, 22.75, 23.0, 23.25, 23.5, 23.75,

24.0, 24.25, 24.5, 24.75]

x29 = []

for i in range(0, 96):

x29 += [1 \* (math.sqrt(((xc - points29[i][0]) \*\* 2) + ((yc - points29[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points29[i][2]) \*\* 2)))]

f29 = plt.figure()

x29 = x29[2:96] + x29[0:2]

el29 = el29[2:96] + el29[0:2]

plt.title("29\" elevation")

plt.plot(y, x29, label="point cloud")

plt.plot(y, el29, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("29.png")

plt.close()

x32 = []

for i in range(0, 96):

x32 += [1 \* (math.sqrt(((xc - points32[i][0]) \*\* 2) + ((yc - points32[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points32[i][2]) \*\* 2)))]

f32 = plt.figure()

x32 = x32[2:96] + x32[0:2]

el32 = el32[2:96] + el32[0:2]

plt.title("32\" elevation")

plt.plot(y, x32, label="point cloud")

plt.plot(y, el32, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("32.png")

plt.close()

x35 = []

for i in range(0, 96):

x35 += [1 \* (math.sqrt(((xc - points35[i][0]) \*\* 2) + ((yc - points35[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points35[i][2]) \*\* 2)))]

f35 = plt.figure()

x35 = x35[2:96] + x35[0:2]

el35 = el35[2:96] + el35[0:2]

plt.title("35\" elevation")

plt.plot(y, x35, label="point cloud")

plt.plot(y, el35, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("35.png")

plt.close()

x38 = []

for i in range(0, 96):

x38 += [1 \* (math.sqrt(((xc - points38[i][0]) \*\* 2) + ((yc - points38[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points38[i][2]) \*\* 2)))]

f38 = plt.figure()

x38 = x38[2:96] + x38[0:2]

el38 = el38[2:96] + el38[0:2]

plt.title("38\" elevation")

plt.plot(y, x38, label="point cloud")

plt.plot(y, el38, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("38.png")

plt.close()

x41 = []

for i in range(0, 96):

x41 += [1 \* (math.sqrt(((xc - points41[i][0]) \*\* 2) + ((yc - points41[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points41[i][2]) \*\* 2)))]

f41 = plt.figure()

x41 = x41[2:96] + x41[0:2]

el41 = el41[2:96] + el41[0:2]

plt.title("41\" elevation")

plt.plot(y, x41, label="point cloud")

plt.plot(y, el41, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("41.png")

plt.close()

x44 = []

for i in range(0, 96):

x44 += [1 \* (math.sqrt(((xc - points44[i][0]) \*\* 2) + ((yc - points44[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points44[i][2]) \*\* 2)))]

f44 = plt.figure()

x44 = x44[2:96] + x44[0:2]

el44 = el44[2:96] + el44[0:2]

plt.title("44\" elevation")

plt.plot(y, x44, label="point cloud")

plt.plot(y, el44, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("44.png")

plt.close()

x47 = []

for i in range(0, 96):

x47 += [1 \* (math.sqrt(((xc - points47[i][0]) \*\* 2) + ((yc - points47[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points47[i][2]) \*\* 2)))]

f47 = plt.figure()

x47 = x47[2:96] + x47[0:2]

el47 = el47[2:96] + el47[0:2]

plt.title("47\" elevation")

plt.plot(y, x47, label="point cloud")

plt.plot(y, el47, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("47.png")

plt.close()

x50 = []

for i in range(0, 96):

x50 += [1 \* (math.sqrt(((xc - points50[i][0]) \*\* 2) + ((yc - points50[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points50[i][2]) \*\* 2)))]

f50 = plt.figure()

x50 = x50[2:96] + x50[0:2]

el50 = el50[2:96] + el50[0:2]

plt.title("50\" elevation")

plt.plot(y, x50, label="point cloud")

plt.plot(y, el50, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("50.png")

plt.close()

x52 = []

for i in range(0, 96):

x52 += [1 \* (math.sqrt(((xc - points52[i][0]) \*\* 2) + ((yc - points52[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points52[i][2]) \*\* 2)))]

f52 = plt.figure()

x52 = x52[2:96] + x52[0:2]

el52 = el52[2:96] + el52[0:2]

plt.title("52\" elevation")

plt.plot(y, x52, label="point cloud")

plt.plot(y, el52, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("52.png")

plt.close()

x56 = []

for i in range(0, 96):

x56 += [1 \* (math.sqrt(((xc - points56[i][0]) \*\* 2) + ((yc - points56[i][1]) \*\* 2)) - math.sqrt(

(rc \*\* 2) - ((zc - points56[i][2]) \*\* 2)))]

f56 = plt.figure()

x56 = x56[2:96] + x56[0:2]

el56 = el56[2:96] + el56[0:2]

plt.title("56\" elevation")

plt.plot(y, x56, label="point cloud")

plt.plot(y, el56, color='green', label="physical")

plt.legend(loc='upper left')

plt.xlabel("Wicket Gate")

plt.ylabel("Distance (m)")

plt.savefig("56.png")

plt.close()

"""

x = []

y = []

for point in points:

x += [point[0]]

y += [point[1]]

fig, ax = plt.subplots()

circle2 = plt.Circle((xc, yc), rc, color='b', fill=True)

ax.plot(x, y, 'o')

ax.add\_artist(circle2)

fig.savefig('plotcircles2.png')

"""