Kai Mcconnell

Project 5 Optimization in Tensor Flow

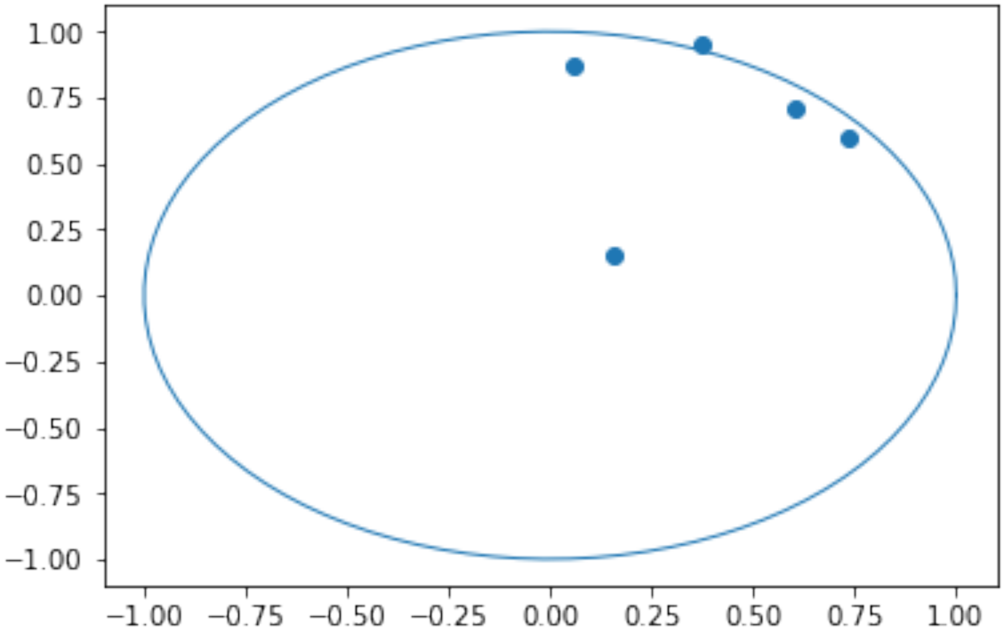
For project 5 I was tasked with optimizing a specific problem using tensorflow. The problem as described was creating a set of N points that were on the unit circle and maximally as far apart as possible. This task therefore involved the creation of a cost function to represent this goal. When creating the cost function I first set out to attach a cost to having points not exactly on the unit circle. This meant that the further a point was from being on the unit circle the greater the cost. This cost could then be minimized by tensor flow by changing the coordinates to be closer and closer to being on the unit circle. The second part of the cost function was maximizing the distance between each point. This was done using the absolute value of the distance formula and subtracting that from the cost. In this way the lower the cost the more likely the points would be far apart. When I combined these two parts together I had the cost function I wanted tensor flow to minimize. At first there were a number of problems I ran into with tensor flows optimization. At first glance I thought I couldn't get the optimization to correctly change the coordinates as the optimized coordinates were the same as my initial coordinates. After some exploration I discovered that the coordinates were being optimized just very slowly which led to the coordinates not appearing to move. Here is an example of how I discovered my problem:

```
Epoch 0 MSE = [[0.37454012 0.95071431]
 [0.73199394 0.59865848]
 [0.15601864 0.15599452]
 [0.05808361 0.86617615]
 [0.60111501 0.70807258]]
Epoch 1000 MSE = [[-0.58157303  0.81560553]
 [ 0.98670475  0.17566026]
 [ 0.68462821  0.68135204]
 [-0.37478525  0.93105531]
 [ 0.70326925  0.71440307]]
Epoch 2000 MSE = [[-0.97401698 -0.24124638]
```

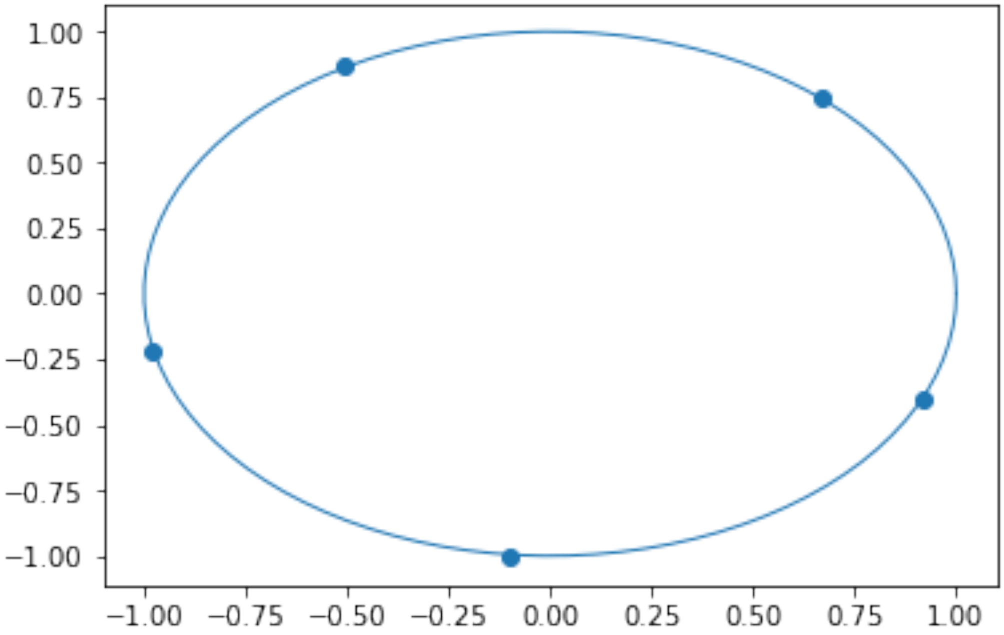
```
 [ 0.88518747 -0.47146224]
 [ 0.70825369  0.70910273]
 [-0.56420262  0.83024325]
 [ 0.8703858   0.49721386]]
Epoch 3000 MSE = [[-0.85650988 -0.52255148]
 [ 0.54537576 -0.84180298]
 [ 0.70213783  0.71585733]
 [-0.67933012  0.73858891]
 [ 0.9760357   0.2297948 ]]
Epoch 4000 MSE = [[-0.88780433 -0.4670619 ]
 [ 0.24658227 -0.9722795 ]
 [ 0.6932305   0.72481702]
 [-0.71794062  0.70067149]
 [ 1.00283047 -0.01224382]]
Epoch 5000 MSE = [[-0.93506202 -0.36312077]
 [ 0.07925774 -0.99992332]
 [ 0.68324733  0.73437081]
 [-0.68387424  0.73376165]
 [ 0.98371259 -0.19574379]]
Epoch 6000 MSE = [[-0.96180561 -0.28478432]
 [-0.01672657 -1.0029283 ]
 [ 0.67408012  0.7428216 ]
 [-0.60088243  0.80313556]
 [ 0.95353952 -0.31122102]]
Epoch 7000 MSE = [[-0.97538098 -0.23409427]
 [-0.07617137 -1.00017909]
 [ 0.66830688  0.74801886]
 [-0.53226266  0.85020068]
 [ 0.92921048 -0.37777479]]
```

```
Epoch 8000 MSE = [[-0.97935369 -0.21686767]
 [-0.09612586 -0.99846094]
 [ 0.66650111  0.7496274 ]
 [-0.50966516  0.86394699]
 [ 0.92004829 -0.39959238]]
Epoch 9000 MSE = [[-0.97976631 -0.21499496]
 [-0.09828698 -0.99825072]
 [ 0.66630958  0.74979756]
 [-0.50725206  0.86536706]
 [ 0.9190237  -0.40194558]]
[[-0.97977459 -0.21495712]
 [-0.09833063 -0.99824643]
 [ 0.66630572  0.74980099]
 [-0.50720339  0.86539561]
 [ 0.91900294 -0.40199308]]
[[0.37454012 0.95071431]
 [0.73199394 0.59865848]
 [0.15601864 0.15599452]
 [0.05808361 0.86617615]
 [0.60111501 0.70807258]]
```

Before I made certain adjustments these values would increase by 0.001 each 1000 epochs which was far to slow to see meaningful change. I solved this by lowering the learning rate and increasing the number of epochs. This lead to my coordinates correctly spreading out and gaining distance from each other however it also led to my coordinates moving far outside the unit circle. I solved this issue by adding additional weights to my cost function to give a coordinate being on the unit circle more of a say on the cost function. This meant that the cost function would spread the coordinates out as far as it could while still keeping them on the unit circle. The culmination of all of this is shown in this example here:



The above set of coordinates was optimized until they became the set of coordinates below.


1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00