Homework 3 Answer

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1 Paper Problems

1.

x_1	x_2	label
1	1	1
1	-1	-1
0	0	-1
-1	3	1

Table 1: Dataset 1

(a)   The hyperplane has a margin for the dataset that is $\frac{1}{\sqrt{13}}$, from the first data point.

x_1	x_2	label
1	1	1
1	-1	-1
0	0	-1
-1	3	1
-1	-1	1

Table 2: Dataset 2

(b)   The hyperplane misclassifies the final data point of dataset 2 so it doesn't have margin.

x_1	x_2	label
-1	0	-1
0	-1	-1
1	0	1
0	1	1

Table 3: Dataset 3

x_1	x_2	label
-1	0	-1
0	-1	1
1	0	-1
0	1	1

Table 4: Dataset 4

2.

    (a) The margin of the dataset 3 is $\frac{1}{\sqrt{2}}$.

    (b) The data from dataset 4 is not linearly separable so there's no margin.

3.

    (a) The upper bound for the number of mistakes will be $(\frac{||\mathbf{u}||R}{\gamma})^2$ if $\mathbf{u}$ is not a unit vector.

    (b) The inequalities should be changed to

$$\frac{y_i(\mathbf{u}^\top \mathbf{x}_i)}{||\mathbf{u}||} \geq \gamma$$

    (c) The upper bound will still be $(\frac{||\mathbf{u}||R}{\gamma})^2$ because the statement is equal to $\frac{y_i(\mathbf{u}^\top \mathbf{x}_i)}{||\mathbf{u}||} \geq \gamma$.

4. Let this function be separated with the hyperplane:

$$-x_1 - \ldots - x_k + x_{k+1} + \ldots + x_{2k} - \frac{1}{2} = 0$$

Then we have

$$R = \sqrt{n+1}$$

Then we know that the closest point to this boundary is the point with all zero attributes which gives

$$\gamma = \frac{\frac{1}{2}}{\sqrt{n + \frac{1}{4}}}$$

Therefore, we get the upper mistake bound of $\frac{(n+1)(n+\frac{1}{4})}{4}$:

$$4n^2 + 5n + 1$$

2

5.

    (a) The VC dimension of $\mathcal{H}$ is 10.

    (b) Generally, for any finite $\mathcal{H}$,

$$VC(\mathcal{H}) = log_2(\mathcal{H})$$

6. Suppose we have a XOR function with 2 binary variables, then we know this function will give 4 distinct points that are not linearly separable which means can't be shattered. Therefore, linear classifiers in a plane can't shatter any 4 distinct points.

7. $VC(\mathcal{H}) = 6$

2 Practice

1. See the github repo

2. (a) Learning rate: 0.1
Learned Weight Vector: [-3.8817654799999937, -3.4242754999999994, -3.1044052000000044, -1.9968752599999975]
Testing Error: 0.05
Training Error: 0.0584862385321

    (b) Learning rate: 0.1

Learned Weight Vector:
Votes   Weight Vector
Votes = 4, w = [-0.40962, -1.01891, 0.39323, 0.41827]
Votes = 4, w = [-0.7556700000000001, -0.7499, 0.409395, 0.31603]
Votes = 5, w = [-1.07454, -0.40847, 0.131975, 0.33629]
Votes = 1, w = [-1.0837594000000002, -0.369155, 0.09912900000000001, 0.322496]
Votes = 1, w = [-1.0789586000000002, -0.208785, -0.7484310000000001, 0.246938]
Votes = 5, w = [-1.2633486000000003, -1.0735350000000001, 0.019528999999999908, 0.18025599999999997]
Votes = 1, w = [-0.9842086000000003, -1.2508750000000002, -0.6580310000000001, 0.22017099999999998]
Votes = 16, w = [-0.7647786000000003, -0.7958450000000001, -1.155631, -0.05236900000000003]
Votes = 1, w = [-0.9676286000000003, -0.4111650000000001, -1.219066, -0.16986900000000005]
Votes = 2, w = [-1.1674586000000002, -1.071885, -0.736526, -0.21185300000000004]
Votes = 5, w = [-1.8182986000000003, -0.1949249999999999, -0.713335, -0.605553]
Votes = 4, w = [-1.8061726000000002, -0.1725779999999999, -0.7606620000000001, -0.508529]
Votes = 1, w = [-2.1757826000000002, -1.540368, 0.9972880000000001, -0.7703390000000001]
Votes = 4, w = [-2.0024726000000004, -1.144928, 0.5231680000000001, -1.020509]
Votes = 20, w = [-2.1921426000000004, -0.8932979999999999, 0.24223800000000006,

-0.9407670000000001]
Votes = 6, w = [-2.0663826000000003, -1.0522179999999999, -0.4585419999999999, -0.9832220000000002]
Votes = 7, w = [-2.0449516, -1.1217469999999998, -0.3708309999999999, -0.9535690000000001]
Votes = 5, w = [-1.8431816, -0.9419269999999998, -0.6666409999999999, -0.9325790000000002]
Votes = 9, w = [-1.8951316, -0.6155969999999998, -0.975591, -0.8340890000000002]
Votes = 1, w = [-1.6303416, -1.629337, -0.842491, -0.28701900000000014]
Votes = 3, w = [-1.6668475999999999, -1.340057, -1.207101, -0.5930490000000002]
Votes = 1, w = [-1.4276775999999998, -0.884407, -1.705981, -0.8829190000000002]
Votes = 49, w = [-1.5798775999999997, -1.548237, -1.131071, -0.8936100000000002]
Votes = 6, w = [-1.5058105999999996, -1.375247, -1.450701, -0.9081800000000002]
Votes = 27, w = [-1.7179105999999995, -1.380835, -1.255801, -0.7728800000000002]
Votes = 7, w = [-1.5827305999999994, -1.274885, -1.490171, -0.7328820000000003]
Votes = 16, w = [-1.9333305999999995, -2.531555, 0.025889000000000273, -0.8080980000000002]
Votes = 6, w = [-2.2210305999999993, -2.125565, -0.33670099999999975, -0.7755540000000002]
Votes = 16, w = [-2.160299599999999, -1.730125, -0.8139009999999998, -1.2240840000000002]
Votes = 4, w = [-2.1536866999999993, -1.480985, -1.1079109999999999, -1.2862400000000003]
Votes = 28, w = [-2.1866106999999992, -1.035465, -1.5650909999999998, -1.1873600000000002]
Votes = 3, w = [-2.208004699999999, -1.103752, -1.5554377999999998, -1.0677100000000002]
Votes = 2, w = [-1.9381146999999992, -2.323592, -1.6230987999999997, -0.21289000000000013]
Votes = 5, w = [-1.8325946999999991, -2.205022, -1.8872087999999998, -0.20185700000000012]
Votes = 29, w = [-2.102874699999999, -2.041752, -1.8036107999999997, -0.2109963000000001]
Votes = 1, w = [-1.8997746999999992, -1.8565519999999998, -2.1048207999999997, -0.2106960000000001]
Votes = 3, w = [-2.443914699999999, -1.1329219999999998, -2.0938828, -0.9671160000000001]
Votes = 43, w = [-2.4978146999999993, -1.649622, -1.7498927999999998, -0.9619019000000001]
Votes = 4, w = [-2.375834699999999, -1.4398019999999998, -2.0694328, -0.9490589]
Votes = 3, w = [-2.445713699999999, -1.7775119999999998, -1.6573228, -0.7986289]
Votes = 11, w = [-2.313883699999999, -1.5873419999999998, -1.9884328, -0.7921218]
Votes = 3, w = [-2.820643699999999, -2.106112, -0.9457727999999999, -0.8788468]
Votes = 7, w = [-2.793766699999999, -1.607412, -1.4608528, -1.5179768]
Votes = 27, w = [-2.756129699999999, -1.68977, -1.3823098, -1.4434528]
Votes = 16, w = [-2.6549596999999987, -1.59955, -1.6173698, -1.4007388]
Votes = 40, w = [-2.6574910999999988, -1.616933, -1.6287088, -1.2787588]
Votes = 20, w = [-2.4993910999999986, -1.530024, -1.8600888000000002, -1.1963468000000002]
Votes = 9, w = [-2.6675910999999988, -2.211234, -1.1461088000000001, -1.0631168000000002]
Votes = 5, w = [-2.6793070999999986, -2.150812, -1.1846958, -1.0690233000000002]
Votes = 2, w = [-2.5113170999999985, -1.7301320000000002, -1.6386758000000001, -1.3083333000000001]
Votes = 7, w = [-2.4093770999999986, -1.6198420000000002, -1.8686758, -1.2489383]
Votes = 30, w = [-2.4266730999999986, -1.7380020000000003, -1.7304958000000001, -1.1755783]
Votes = 5, w = [-2.5869630999999984, -1.7769050000000002, -1.5684958, -0.9845482999999999]
Votes = 165, w = [-2.5865576499999983, -1.7140000000000002, -1.6326168, -0.9087312999999999]

4

Votes = 25, w = [-2.5835357499999985, -1.8191200000000003, -1.4923768000000002, -0.8313622999999999]

Votes = 8, w = [-2.4607457499999983, -1.4160300000000003, -1.9567268000000002, -1.2226123]

Votes = 11, w = [-2.821275749999998, -2.0134300000000005, -0.9475668000000002, -1.3054583]

Votes = 33, w = [-2.791194749999998, -1.9960490000000004, -1.1229868, -1.2565373]

Votes = 11, w = [-2.7687627499999983, -2.0481960000000003, -1.1633728, -1.1363672999999999]

Votes = 12, w = [-2.617992749999998, -1.8522360000000004, -1.4692128000000002, -1.1486102999999999]

Votes = 8, w = [-2.472982749999998, -1.4915660000000004, -1.8747828000000002, -1.3082702999999998]

Votes = 6, w = [-2.4386427499999983, -1.4791510000000003, -1.9035158, -1.2936162999999998]

Votes = 6, w = [-2.3868427499999982, -1.4532860000000003, -1.9876008, -1.1974983]

Votes = 8, w = [-2.3081527499999983, -2.4099160000000004, -1.6089308, -0.4471582999999999]

Votes = 3, w = [-2.898492749999998, -1.7531260000000004, -1.5412698, -1.1151282999999999]

Votes = 7, w = [-2.8340207499999983, -1.2925060000000004, -2.3759698, -0.8441382999999998]

Votes = 1, w = [-3.1290007499999986, -2.1198060000000005, -1.3495098, -0.7278482999999998]

Votes = 6, w = [-3.1809507499999987, -1.7934760000000005, -1.6584598000000002, -0.6293582999999998]

Votes = 10, w = [-3.1250117499999988, -1.8245160000000005, -1.6401528, -0.5847052999999998]

Votes = 4, w = [-3.1579317499999986, -1.3789960000000006, -2.0973328, -0.48582529999999974]

Votes = 37, w = [-3.2236987499999987, -1.6591760000000007, -1.7261828000000001, -0.3860862999999997]

Votes = 16, w = [-3.118178749999999, -1.5406060000000006, -1.9902928000000002, -0.3750532999999997]

Votes = 1, w = [-2.982998749999999, -1.4346560000000006, -2.2246628000000004, -0.335055299999997]

Votes = 12, w = [-3.0456827499999988, -2.064756000000001, -1.7462328000000005, -0.2244552999999997]

Votes = 1, w = [-3.0242517499999986, -2.134285000000001, -1.6585218000000004, -0.19480229999999968]

Votes = 22, w = [-2.7850817499999985, -1.678635000000012, -2.1574018000000006, -0.4846722999999997]

Votes = 3, w = [-2.9383017499999986, -2.188295000000001, -1.4896118000000005, -0.4671742999999997]

Votes = 8, w = [-2.9875827499999987, -1.882245000000001, -1.6731718000000004, -0.7505742999999998]

Votes = 3, w = [-3.039532749999999, -1.555915000000001, -1.9821218000000005, -0.6520842999999998]

Votes = 3, w = [-2.836432749999999, -1.370715000000001, -2.2833318000000005, -0.6517839999999998]

Votes = 5, w = [-2.802092749999999, -1.358300000000001, -2.3120648000000004, -0.6371299999999998]

Votes = 3, w = [-2.900632749999999, -2.024400000000001, -1.7296148000000002,

-0.5825199999999997]
Votes = 34, w = [-2.721882749999999, -1.5464000000000009, -2.2432348, -0.9061399999999997]
Votes = 3, w = [-2.718860849999999, -1.651520000000001, -2.1029948000000003, -0.8287709999999997]
Votes = 15, w = [-2.596880849999999, -1.4417000000000009, -2.4225348, -0.8159279999999997]
Votes = 3, w = [-2.8290908499999987, -2.374740000000001, -1.4992348, -0.8957989999999997]
Votes = 52, w = [-3.3457008499999987, -1.5704100000000007, -1.4948082999999999, -1.3456289999999997]
Votes = 13, w = [-3.411708849999999, -1.8930100000000007, -1.1142282999999997, -1.2272689999999997]
Votes = 6, w = [-3.355769849999999, -1.9240500000000007, -1.0959212999999997, -1.1826159999999997]
Votes = 35, w = [-3.1976698499999987, -1.8371410000000008, -1.3273012999999998, -1.1002039999999997]
Votes = 5, w = [-3.1414378499999986, -1.7369910000000008, -1.5545612999999998, -1.1008088599999997]
Votes = 1, w = [-3.0709478499999987, -1.7198170000000008, -1.7331512999999998, -1.0646898599999997]
Votes = 1, w = [-3.0705423999999986, -1.6569120000000008, -1.7972723, -0.9888728599999996]
Votes = 16, w = [-2.9115023999999985, -1.435702000000001, -2.1091023, -1.0005978599999996]
Votes = 5, w = [-3.0281723999999985, -1.578072000000001, -1.8166923, -0.9344788599999996]
Votes = 55, w = [-2.9763723999999985, -1.552207000000001, -1.9007773, -0.8383608599999995]
Votes = 37, w = [-2.9019443999999983, -1.929437000000001, -1.7394672999999998, -0.6808208599999995]
Votes = 18, w = [-2.934864399999998, -1.483917000000001, -2.1966473, -0.5819408599999996]
Votes = 3, w = [-3.2298443999999984, -2.311217000000001, -1.1701873, -0.46565085999999956]
Votes = 32, w = [-3.1234743999999983, -1.941647000000001, -1.5861273, -0.6594408599999996]
Votes = 55, w = [-3.165439399999998, -1.650707000000001, -1.7647173, -0.8801308599999996]
Votes = 22, w = [-3.1430073999999983, -1.702854000000001, -1.8051033, -0.7599608599999996]
Votes = 46, w = [-3.1186133999999983, -1.555524000000001, -1.9470233000000001, -0.8184958599999996]
Votes = 2, w = [-3.1064873999999985, -1.5331770000000011, -1.9943503000000002, -0.7214718599999996]
Votes = 8, w = [-2.8870573999999984, -1.078147000000001, -2.4919503, -0.9940118599999996]
Votes = 2, w = [-3.0427773999999985, -2.0662270000000014, -1.6810703, -1.1020718599999997]
Votes = 1, w = [-2.9109473999999986, -1.8760570000000014, -2.0121803, -1.0955647599999996]
Votes = 14, w = [-2.709177399999999, -1.6962370000000013, -2.3079902999999997, -1.0745747599999995]
Votes = 65, w = [-2.8328673999999987, -1.8652970000000013, -2.0561903, -1.0229387599999995]
Votes = 29, w = [-2.9717373999999985, -2.3530270000000013, -1.4084502999999997, -0.9887597599999995]
Votes = 14, w = [-2.8979773999999985, -1.8677770000000014, -1.8883102999999997, -1.5553497599999995]
Votes = 21, w = [-2.9005087999999986, -1.8851600000000013, -1.8996492999999997, -1.4333697599999995]

Votes = 74, w = [-2.9178047999999985, -2.0033200000000013, -1.7614692999999997, -1.3600097599999994]

Votes = 2, w = [-2.9835717999999987, -2.2835000000000014, -1.3903192999999996, -1.2602707599999994]

Votes = 23, w = [-2.810261799999999, -1.8880600000000014, -1.8644392999999997, -1.5104407599999994]

Votes = 28, w = [-2.9705517999999986, -1.9269630000000013, -1.7024392999999995, -1.3194107599999993]

Votes = 3, w = [-2.9329147999999985, -2.0093210000000012, -1.6238962999999995, -1.2448867599999993]

Votes = 7, w = [-2.7839547999999983, -1.6664410000000012, -2.0269862999999995, -1.3874767599999993]

Votes = 9, w = [-3.2216847999999985, -2.2181110000000013, -0.9330862999999994, -1.4282967599999994]

Votes = 18, w = [-3.2055767999999984, -1.5718710000000011, -1.7688162999999995, -1.2761367599999993]

Votes = 17, w = [-3.1268867999999985, -2.528501000000001, -1.3901462999999994, -0.5257967599999993]

Votes = 31, w = [-3.1066707999999985, -2.3366810000000013, -1.7184262999999995, -0.5875647599999994]

Votes = 6, w = [-3.1395947999999985, -1.8911610000000014, -2.1756062999999997, -0.48868475999999933]

Votes = 14, w = [-3.1181637999999983, -1.9606900000000014, -2.0878952999999996, -0.45903175999999934]

Votes = 4, w = [-3.188042799999998, -2.2984000000000013, -1.6757852999999996, -0.30860175999999934]

Votes = 25, w = [-3.187637349999998, -2.235495000000001, -1.7399062999999997, -0.2327847599999993]

Votes = 17, w = [-3.1337013499999977, -1.8460550000000011, -2.2215662999999997, -0.6669647599999993]

Votes = 30, w = [-2.9829313499999977, -1.6500950000000012, -2.5274062999999996, -0.6792077599999993]

Votes = 13, w = [-2.979909449999998, -1.755215000000001, -2.3871662999999996, -0.6018387599999993]

Votes = 7, w = [-3.401009449999998, -3.002575000000001, -0.8901262999999995, -0.7406787599999993]

Votes = 4, w = [-3.339357449999998, -2.613135000000001, -1.3628762999999995, -1.1801587599999994]

Votes = 10, w = [-3.390173449999998, -2.326335000000001, -1.5439562999999996, -1.4062787599999995]

Votes = 31, w = [-3.352536449999998, -2.4086930000000013, -1.4654132999999996, -1.3317547599999995]

Votes = 20, w = [-3.173786449999998, -1.9306930000000013, -1.9790332999999996, -1.6553747599999995]

Votes = 10, w = [-3.225736449999998, -1.6043630000000013, -2.2879832999999996,

7

-1.5568847599999995]
Votes = 19, w = [-3.365416449999998, -2.5713430000000015, -1.3414632999999996, -1.5917567599999995]
Votes = 6, w = [-3.259896449999998, -2.4527730000000014, -1.6055732999999996, -1.5807237599999995]
Votes = 18, w = [-3.292816449999998, -2.0072530000000013, -2.0627533, -1.4818437599999994]
Votes = 8, w = [-3.236877449999998, -2.0382930000000012, -2.0444462999999997, -1.4371907599999993]
Votes = 28, w = [-3.078777449999998, -1.9513840000000013, -2.2758263, -1.3547787599999994]
Votes = 3, w = [-3.0269774499999977, -1.9255190000000013, -2.3599113, -1.2586607599999995]
Votes = 11, w = [-2.948287449999998, -2.8821490000000014, -1.9812412999999998, -0.5083207599999995]
Votes = 15, w = [-3.451297449999998, -2.1318290000000015, -1.9946372999999997, -1.2586607599999995]
Votes = 6, w = [-3.453828849999998, -2.1492120000000017, -2.0059763, -1.1366807599999995]
Votes = 16, w = [-3.294788849999998, -1.9280020000000015, -2.3178063, -1.1484057599999995]
Votes = 50, w = [-3.548518849999998, -2.6239020000000015, -1.4372662999999999, -0.9955157599999995]
Votes = 18, w = [-3.478028849999998, -2.6067280000000017, -1.6158563, -0.9593967599999995]
Votes = 11, w = [-3.489744849999998, -2.5463060000000017, -1.6544432999999998, -0.9653032599999996]
Votes = 2, w = [-3.572345849999998, -2.2501960000000016, -1.7830833, -1.1117732599999997]
Votes = 33, w = [-3.399035849999998, -1.8547560000000016, -2.2572033, -1.3619432599999997]
Votes = 5, w = [-3.515705849999998, -1.9971260000000015, -1.9647933, -1.2958242599999996]
Votes = 4, w = [-3.4932738499999982, -2.0492730000000017, -2.0051793, -1.1756542599999995]
Votes = 38, w = [-3.392103849999998, -1.9590530000000017, -2.2402393, -1.1329402599999996]
Votes = 5, w = [-3.256923849999998, -1.8531030000000017, -2.4746093, -1.0929422599999996]
Votes = 13, w = [-3.244797849999998, -1.8307560000000018, -2.5219363, -0.9959182599999996]
Votes = 33, w = [-3.316865849999998, -2.5065860000000018, -1.9378563, -0.9335492599999996]
Votes = 20, w = [-3.077695849999998, -2.050936000000002, -2.4367363, -1.2234192599999996]
Votes = 6, w = [-2.975755849999998, -1.9406460000000019, -2.6667363, -1.1640242599999995]
Votes = 1, w = [-3.3453658499999976, -3.308436000000002, -0.9087863, -1.4258342599999996]
Votes = 6, w = [-3.2771858499999977, -2.823396000000002, -1.4301163000000001, -2.0362642599999994]
Votes = 4, w = [-3.2527918499999977, -2.676066000000002, -1.5720363000000002, -2.0947992599999994]
Votes = 3, w = [-3.1319918499999977, -2.268626000000002, -2.0483863, -2.356089259999999]
Votes = 30, w = [-3.097651849999998, -2.256211000000002, -2.0771193, -2.341435259999999]
Votes = 3, w = [-3.138455849999998, -2.201997000000002, -2.1298443000000002, -2.275575259999999]
Votes = 6, w = [-2.873665849999998, -3.2157370000000025, -1.9967443000000002, -1.728505259999999]
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Votes = 15, w = [-3.2088178499999978, -2.9152870000000024, -2.1259843000000003, -1.5541609599999986]
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Votes = 10, w = [-3.073038849999997, -2.0975205000000026, -2.6301811000000006, -1.9970198599999984]
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9

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Votes = 8, w = [-3.3656039499999975, -2.2537775000000018, -2.432694100000001, -1.9949258599999984]

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Votes = 26, w = [-3.2413699499999975, -2.2788175000000015, -3.0144241000000003, -1.6550597599999983]

Votes = 40, w = [-3.7047499499999974, -3.5539075000000016, -1.3427641000000001, -1.9767397599999983]

Votes = 21, w = [-3.7455539499999975, -3.4996935000000016, -1.3954891, -1.9108797599999983]

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Votes = 12, w = [-4.0577098499999975, -2.5378885000000015, -2.6959851, -1.3563277599999986]

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Votes = 4, w = [-3.9020567999999978, -3.0314345000000023, -1.8750230999999995, -1.552481559999999]

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Votes = 18, w = [-3.500986549999998, -1.9086615000000018, -3.0762500999999993, -1.555697159999999]

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Votes = 20, w = [-3.596147549999998, -2.370114500000002, -2.849560099999999, -1.276357159999999]

Votes = 14, w = [-4.0637975499999985, -2.936474500000002, -1.7526600999999988, -1.309806159999999]

Votes = 40, w = [-4.096717549999998, -2.4909545000000017, -2.2098400999999988, -1.210926159999999]

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Votes = 35, w = [-3.700494019999998, -2.877529500000002, -2.6602360999999988, -1.2915295199999992]
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Votes = 15, w = [-4.039147119999998, -2.3413975000000025, -2.3923390999999987, -1.694429319999999]

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Votes = 7, w = [-4.252277409999996, -2.920133500000004, -1.8443251600000001, -2.0602946400000013]
Votes = 26, w = [-4.236169409999996, -2.273893500000004, -2.68005516, -1.9081346400000012]
Votes = 15, w = [-4.396459409999996, -2.3127965000000037, -2.5180551600000003, -1.7171046400000012]
Votes = 7, w = [-4.245689409999996, -2.116836500000004, -2.82389516, -1.7293476400000012]
Votes = 24, w = [-4.223257409999996, -2.168983500000004, -2.86428116, -1.6091776400000013]

Votes = 34, w = [-4.167318409999996, -2.200023500000004, -2.84597416, -1.5645246400000012]
Votes = 6, w = [-4.421048409999996, -2.895923500000004, -1.9654341599999998, -1.4116346400000013]
Votes = 7, w = [-4.414435509999995, -2.6467835000000037, -2.2594441599999997, -1.4737906400000014]
Votes = 18, w = [-4.3132655099999955, -2.5565635000000038, -2.4945041599999995, -1.4310766400000015]
Votes = 2, w = [-4.207745509999995, -2.4379935000000037, -2.7586141599999996, -1.420436400000014]
Votes = 9, w = [-4.129055509999995, -3.394623500000004, -2.3799441599999995, -0.6697036400000014]
Votes = 19, w = [-4.129184029999995, -3.3807605000000036, -2.3995951599999996, -0.6688861000000014]
Votes = 11, w = [-4.749214029999995, -2.512700500000004, -2.3986817199999995, -1.0391861000000013]
Votes = 35, w = [-4.617384029999995, -2.3225305000000036, -2.7297917199999997, -1.0326790000000012]
Votes = 4, w = [-4.595953029999995, -2.392059500000004, -2.6420807199999996, -1.0030260000000013]
Votes = 22, w = [-4.661961029999995, -2.7146595000000038, -2.2615007199999995, -0.8846660000000013]
Votes = 27, w = [-4.572449029999995, -2.2372795000000036, -2.7458107199999997, -1.4437560000000014]
Votes = 9, w = [-4.353019029999995, -1.7822495000000036, -3.24341072, -1.7162960000000014]
Votes = 71, w = [-4.430307029999995, -2.526979500000004, -2.59421072, -1.6801770000000014]
Votes = 4, w = [-4.227207029999995, -2.341779500000004, -2.89542072, -1.6798767000000014]
Votes = 11, w = [-4.297086029999996, -2.679489500000004, -2.48331072, -1.5294467000000014]
Votes = 2, w = [-4.294064129999995, -2.7846095000000037, -2.34307072, -1.4520777000000014]
Votes = 17, w = [-4.305780129999995, -2.7241875000000038, -2.38165772, -1.4579842000000014]
Votes = 3, w = [-4.3053746799999955, -2.6612825000000035, -2.4457787200000003, -1.3821672000000014]
Votes = 1, w = [-4.357324679999995, -2.3349525000000035, -2.75472872, -1.2836772000000014]
Votes = 8, w = [-4.198284679999995, -2.1137425000000034, -3.06655872, -1.2954022000000014]
Votes = 8, w = [-3.9965146799999953, -1.9339225000000033, -3.36236872, -1.2744122000000013]
Votes = 3, w = [-4.149034679999995, -2.5592625000000035, -2.82712872, -1.2145002000000014]
Votes = 10, w = [-4.136908679999995, -2.5369155000000037, -2.8744557200000003, -1.1174762000000014]
Votes = 7, w = [-4.139440079999995, -2.554298500000004, -2.8857947200000003, -0.9954962000000014]
Votes = 22, w = [-3.9714500799999946, -2.133618500000004, -3.3397747200000003, -1.2348062000000013]
Votes = 42, w = [-4.483610079999995, -2.664798500000004, -2.30131472, -1.3409262000000013]
Votes = 13, w = [-4.3608200799999945, -2.2617085000000037, -2.76566472, -1.7321762000000014]
Votes = 40, w = [-4.323183079999994, -2.344066500000004, -2.6871217200000004,

-1.6576522000000014]
Votes = 21, w = [-4.340479079999994, -2.462226500000004, -2.54894172, -1.5842922000000013]
Votes = 72, w = [-4.288679079999994, -2.436361500000004, -2.63302672, -1.4881742000000013]
Votes = 1, w = [-4.109929079999994, -1.9583615000000039, -3.14664672, -1.8117942000000014]
Votes = 13, w = [-4.531029079999994, -3.2057215000000037, -1.64960672, -1.9506342000000014]
Votes = 17, w = [-4.460539079999994, -3.188547500000004, -1.82819672, -1.9145152000000014]
Votes = 26, w = [-4.400489079999994, -3.088602500000004, -2.0494567200000002, -1.9047753000000014]
Votes = 7, w = [-4.441293079999993, -3.034388500000004, -2.1021817200000004, -1.8389153000000014]

Testing Error: 0.054
Training Error: 0.0470183486239

(c) Learning rate: 0.1
Learned Weight Vector: [-32545.392419189826, -21499.0404075003, -19988.892427319413, -11745.692276840055]
Testing Error: 0.06
Training Error: 0.0470183486239

The average weight vector is almost the same as the sum of weight vectors from (b).

(d) Standard Perceptron result has the best testing error in 0.05 but the worst training error in about 0.058. Voted and Average Perceptron has the same training error as expected.