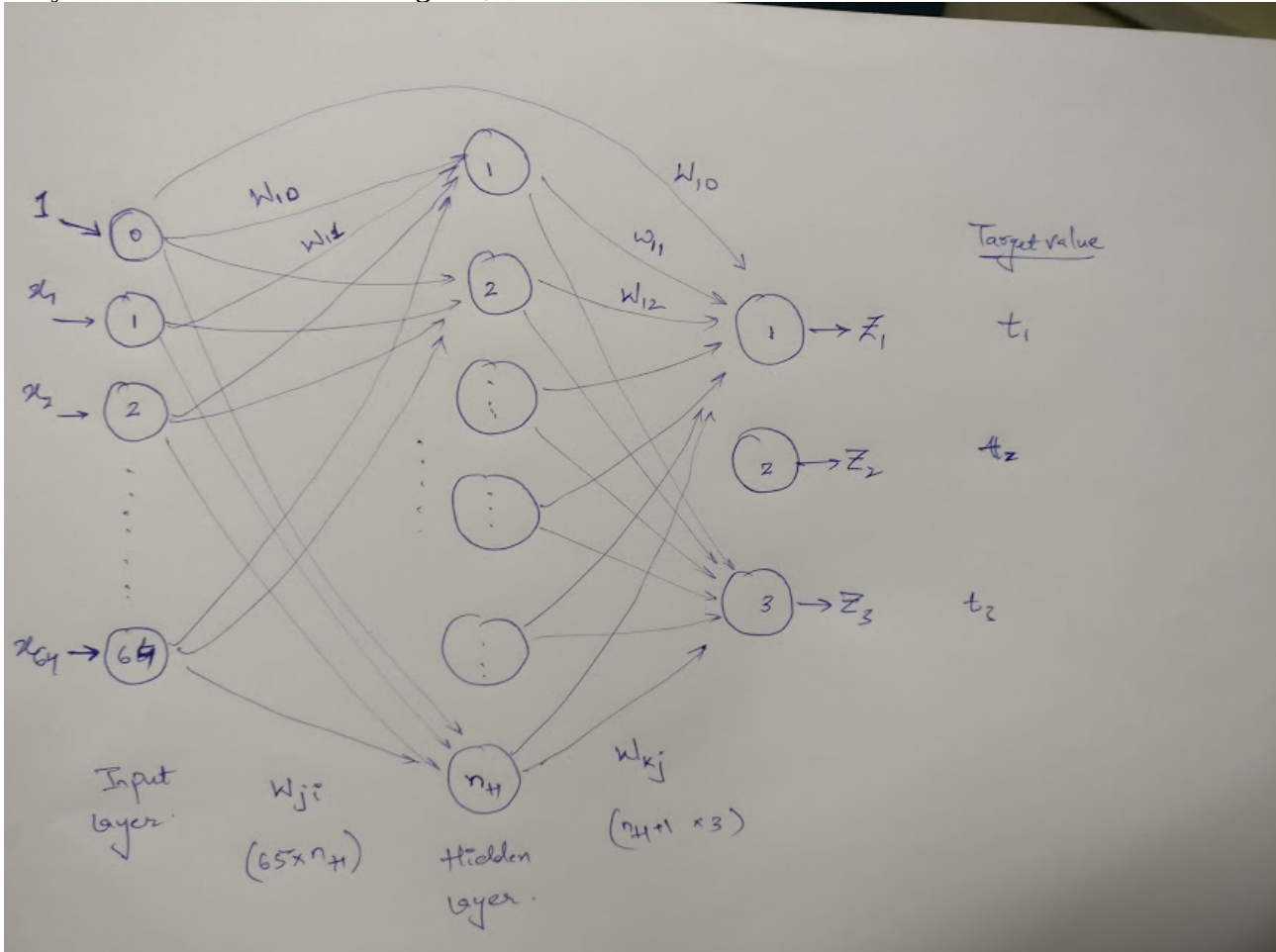


SMAI Assignment 4

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20162078

Question 1:

3 layer NN was trained on for digits 0, 1 and 2.



Results:

Accuracy increases as we increase the number of hidden layers, but increasing it beyond a point decreases the accuracy due to overfitting.

n_H : 3

W_{kj} :

```
[[ 6.51873011 -5.78015007 -3.81029633 -0.55864887 -0.18939289 -0.41286663
  -0.21504822 -0.83341995 -0.65461668 -0.73768656]
 [ 0.10621583 5.55604157 -5.75395014 -2.301474 -1.85265645 -1.51776809
  -1.66947095 -1.77738882 -1.53970962 -1.52042605]
 [ 0.39978092 0.36548636 -0.21812307 0.4987348 0.72643966 0.95348869
  1.00674682 -1.36778173 -0.55137532 0.70264977]
 [-3.39748584 -2.88948693 2.76091156 -3.54923483 -3.59013506 -3.61156605
  -3.60606829 -3.56761535 -3.59507873 -3.59541682]]
```

W_{ji} :

```
[[ -1.59002627e-01 -1.56146718e-01 -1.31693873e-02]
 [ -1.49692720e-01 -5.23480965e-01 -9.26452994e-02]]
```

[-3.04112837e-01 -1.05924117e+00 -1.33887372e-01]
[-1.89693027e-01 -4.35589871e-01 -2.30492566e-01]
[-4.05023043e-01 -4.55038504e-01 -2.97976367e-02]
[-4.94368159e-01 2.27048545e-01 -5.85465355e-02]
[-2.50670220e-01 2.81358028e-02 4.25967241e-02]
[-1.29283760e-02 2.06370091e-02 1.81100764e-01]
[-2.30565926e-02 -4.69998524e-02 -9.65978711e-02]
[-3.19342280e-01 -6.90449309e-01 4.91097706e-04]
[-2.22898887e-02 -1.93222637e+00 -9.69330663e-02]
[-1.54640420e-01 -1.28562900e-01 -2.55716254e-01]
[-1.17886575e-01 -5.18289876e-01 -2.76021926e-01]
[-1.79039216e-01 1.76480915e-01 -2.17142298e-01]
[-1.07686508e-01 -2.60225027e-02 -1.27733220e-01]
[-6.05217204e-02 -6.88728724e-03 -1.30504008e-01]
[8.69109118e-02 -1.19182003e-01 1.78523758e-01]
[-9.34922732e-02 -1.64379182e-01 -3.57359534e-02]
[-5.42891734e-02 8.75665454e-01 -4.47986042e-02]
[-6.55726266e-01 2.04191994e+00 -1.83406031e-01]
[-8.42913755e-01 -2.88360309e-01 -3.60904814e-02]
[7.56062310e-01 1.80626220e-01 1.05876758e-01]
[5.95622211e-01 3.61500967e-01 1.18111139e-01]
[-2.25973282e-02 -1.86198054e-01 -3.62627098e-02]
[-1.07918524e-01 -1.21394454e-02 -2.91126048e-02]
[5.19893584e-01 4.54062695e-01 -4.13326097e-02]
[4.39472497e-01 1.51979412e+00 -9.00900396e-02]
[-8.36762388e-01 1.98355012e+00 -1.00746927e-01]
[-1.12342174e+00 -2.68725482e-01 5.30256000e-02]
[2.81573121e-01 3.56839908e-01 1.65503372e-01]
[8.66628846e-01 9.82640471e-01 -1.54151677e-01]
[-8.06734759e-02 5.81290243e-02 -4.78985707e-02]
[-4.11765857e-02 7.44119072e-02 2.48426211e-02]
[5.58401576e-01 1.01365532e+00 -1.24788548e-01]
[7.38133118e-01 9.52067092e-01 -1.61820896e-02]
[-6.47428017e-01 9.73166515e-01 2.15491184e-01]
[-9.07977818e-01 5.07884737e-01 -1.53513995e-01]
[1.28025676e-01 5.11717342e-01 -1.02289722e-01]
[1.26659992e+00 1.17798335e+00 9.58962202e-03]
[1.44928529e-01 1.50444807e-01 1.36040085e-01]
[6.32694366e-02 -3.68634481e-02 1.07797469e-01]
[3.66492364e-01 3.50341877e-01 1.22304619e-01]
[1.45161443e+00 2.25366005e-01 1.00237374e-01]
[-3.53036506e-01 -2.96765423e-01 -6.06687631e-02]
[-8.85413531e-01 1.32247190e+00 -3.30341177e-02]
[6.42285216e-01 1.60101427e+00 2.34332976e-01]
[3.43171083e-01 8.47090698e-01 5.38962003e-02]
[-9.78656801e-02 -2.82072735e-01 -2.25106092e-01]
[-1.19344446e-01 -3.58376589e-01 -1.33117716e-02]
[-3.17373384e-01 -1.08043518e+00 1.55023465e-01]
[2.89203215e-01 -6.03408417e-01 1.31672347e-01]
[2.52831551e-01 -9.21073898e-01 5.48508703e-02]
[-1.77862351e-01 -1.57302962e-02 -2.18912857e-02]
[1.36262423e-01 6.34288790e-02 4.25364241e-02]

[-5.31576477e-01 -1.20554480e+00 -2.47012667e-01]
[5.81976178e-02 1.56190564e-01 -3.46670466e-02]
[-7.69306817e-02 -1.41487334e-01 -4.16877526e-02]
[-3.80870580e-02 -3.31336791e-01 2.88707403e-02]
[-5.52526927e-01 -1.18474633e+00 -2.78282846e-01]
[1.19780826e-01 -1.21424403e-01 2.62616171e-02]
[1.86087306e-02 8.03705310e-01 1.46204897e-02]
[-1.08806313e+00 -7.59360925e-01 8.06919580e-02]
[-1.11759375e+00 -1.41862633e+00 9.32415723e-02]
[-2.34292393e-01 4.74378690e-01 7.95151787e-02]
[1.38314232e-02 -2.15934174e-01 -1.18966876e-01]]

Accuracy: 98.32%

nH: 10

Wkj:

[[0.98265896 -2.13640212 0.63088125 -0.72044259 -0.73782109 -0.93748716
-0.66853736 -0.6516938 -0.70722604 -0.84470059]
[-1.09335961 -0.93298612 2.19860932 -0.77438546 -0.63025267 0.243041
0.01361477 -0.35750324 -0.11619876 -0.0515506]
[-0.34611124 0.04393775 0.70070612 0.1803989 0.23940322 0.41167403
-0.1290875 -0.31386462 0.56560893 0.41209011]
[0.08328601 -0.43479343 -0.35714155 -0.95007375 -1.1599837 -1.27120411
-0.75429194 -1.02355653 -1.2848597 -1.08800108]
[1.18201936 1.70146417 -3.25479167 -1.004264 -0.80092946 -0.07804529
-0.94671015 -0.62096765 -0.61348851 -0.52698818]
[0.24982811 -0.46424324 -0.71452432 -1.03676729 -0.66966573 -1.25998169
-0.8139464 -0.96815754 -0.66148273 -0.391019]
[-2.24619165 1.23227477 0.47281275 -0.47717635 -0.30261812 -0.21431462
-0.51126529 -0.40023964 -0.36869971 -0.86386451]
[-0.27789343 0.08488696 -0.14239024 -0.12043479 0.70102753 0.27231229
0.02268378 0.38056604 0.12490261 0.19110521]
[-2.65608914 1.2999284 1.11445459 -0.31247842 -0.66832819 -0.41385228
-0.42815201 -0.06781304 -0.27292285 -0.3937375]
[1.25752427 -2.3844431 1.18040283 -0.21791243 -0.47830182 0.05615149
-0.30731021 -0.49024436 -0.34811133 -0.56002543]
[-0.32429691 -0.03196466 -0.89956741 -0.59719243 -0.70796888 -1.14380969
-1.15929413 -1.15582136 -1.13913293 -1.1065398]]

Wji:

[[9.24431780e-02 -4.00346590e-02 1.40956772e-01 8.32906539e-02
4.32713403e-02 2.15910546e-02 1.71281212e-01 -3.58667731e-02
2.89892907e-01 2.51916281e-01]
[-1.39078842e-01 1.47524568e-01 -2.28913617e-02 5.44659591e-02
-9.69968417e-02 2.11974001e-04 -3.43409617e-02 -5.15306537e-02
1.61992768e-02 3.34997018e-01]
[1.71503917e-01 2.10936470e-01 -9.59511523e-02 1.12721684e-01
-9.73381372e-02 -8.57593277e-02 1.86757999e-01 -1.56894431e-01
2.26529490e-01 3.68911585e-01]
[1.34901467e-01 -9.72119688e-03 -2.00799527e-01 9.55270185e-02
-1.99709625e-01 3.15280527e-02 -6.19177732e-03 -1.22943900e-01]

2.25181910e-01 6.90201724e-02]
[-6.08092530e-03 2.90772997e-01 -1.36568282e-01 2.92027711e-02
-2.50487339e-01 -1.14785974e-01 1.89724108e-01 -1.51622350e-02
7.55162682e-02 1.36312441e-01]
[-9.93405172e-02 -2.21987296e-02 1.90721663e-01 5.89423008e-02
-2.34516121e-01 1.34168108e-01 2.27542646e-01 -1.03576702e-01
2.54582483e-01 -6.71888558e-02]
[-1.21547152e-01 -1.06843850e-01 -5.05215043e-02 8.97692041e-02
4.89972071e-02 6.72710879e-03 1.93499870e-01 -1.93992956e-02
1.04563251e-01 4.66327115e-03]
[-1.05688558e-01 -6.68856264e-02 2.62325115e-02 -1.00345402e-01
-1.72809008e-01 -9.65179614e-02 -1.14257554e-01 -5.61248107e-02
-1.32967061e-04 1.18450394e-01]
[4.14629235e-03 -1.81642344e-01 -8.70102084e-02 1.87193991e-01
1.45756788e-01 1.27622732e-01 -2.00557378e-01 6.52057525e-02
-1.43284560e-01 -8.25945204e-02]
[5.12157974e-02 1.16024329e-01 -6.44551438e-02 -1.33818719e-01
-5.78400246e-01 2.30783173e-01 -2.02320998e-02 -4.17295075e-02
1.05941912e-01 1.14947123e-01]
[3.38183759e-01 3.49397833e-01 -2.47295179e-01 2.65347331e-02
-4.45960512e-01 1.89911523e-01 -4.62244210e-02 -2.20410577e-01
-2.05589783e-02 3.63599293e-01]
[1.13935413e-01 -4.89273774e-02 1.38683257e-01 7.99720590e-02
-6.37289841e-02 9.83858094e-02 3.97524843e-02 2.00401220e-01
1.25557311e-01 2.14702866e-02]
[1.32458479e-01 1.76990174e-02 -3.70042157e-03 -2.25573010e-01
-9.98283119e-02 -8.16625207e-02 -7.10562964e-02 8.86752320e-03
-8.65996950e-02 2.02005227e-01]
[-8.36742524e-03 6.47112380e-02 1.64619051e-02 7.81462625e-02
-2.84048643e-03 -3.27615447e-02 -2.46698974e-02 -1.04695458e-01
-2.23924514e-01 1.32107017e-01]
[1.18103793e-01 2.08169494e-02 3.01079367e-01 1.52260693e-01
1.13446756e-01 1.34273613e-01 1.43947241e-01 -3.59784656e-02
7.35286867e-02 4.03184341e-02]
[5.50019101e-02 8.88005050e-02 -4.30760120e-02 4.81197118e-02
-2.38615638e-02 5.18086007e-02 -7.32941145e-02 -1.50840776e-01
-5.99033239e-02 -7.50408035e-02]
[-9.68882856e-04 -1.96084008e-01 -5.80172544e-02 -2.28866651e-01
5.36808527e-03 1.54147115e-01 5.08702523e-02 -9.42051495e-02
-1.25547403e-01 1.55327117e-03]
[-6.69214388e-02 1.80926762e-01 7.25124506e-02 3.59340109e-02
7.00851312e-02 -8.09398081e-02 1.38767087e-01 -2.28941945e-01
1.44484840e-01 -8.96121380e-02]
[-1.83506083e-01 -4.29276545e-02 4.31590561e-02 -1.34075888e-01
3.45074939e-01 -3.79477430e-02 6.83963961e-02 1.19807459e-01
-8.42971625e-03 1.29611599e-02]
[-2.33133152e-01 -2.73673527e-01 -1.20245664e-01 5.44472179e-02
5.04503423e-01 2.20151055e-01 2.81172506e-01 -1.27611446e-01
1.10874988e-01 -5.74523996e-01]
[-1.16144905e-01 -1.21961567e-01 6.48125098e-02 -3.32797421e-02
-3.55928398e-02 -1.31518949e-01 2.60852598e-01 -1.12298164e-01
1.28300967e-01 -7.72466998e-02]

[-6.83282504e-02 -1.42289581e-02 4.71489919e-02 1.18127916e-01
8.12100434e-02 1.93557608e-01 -3.77691252e-02 -3.05876899e-02
-2.24545002e-01 1.21375092e-01]
[1.19702760e-01 -2.39436058e-01 -1.71616861e-01 1.28217690e-03
1.15352446e-01 1.35772339e-01 -9.98215019e-02 -9.97527269e-02
-1.20632828e-01 -1.27942914e-01]
[4.70188111e-02 1.23428885e-01 -8.00005207e-02 8.45472996e-03
2.31005377e-01 -2.58155506e-02 -7.29243789e-02 -7.06580082e-02
5.57720565e-02 -1.08081638e-01]
[9.95943272e-02 2.70458384e-02 6.71199305e-02 2.31581904e-02
-6.03031205e-02 -7.16853097e-02 -5.76707832e-02 -3.02316934e-02
-5.09006751e-02 9.96172000e-02]
[4.60386108e-02 -5.04188800e-02 1.07140199e-01 -9.93226515e-02
-4.04715452e-02 5.76013835e-02 7.70934574e-02 5.59974794e-02
8.65545709e-02 7.03786216e-02]
[-4.91353524e-02 -4.73216375e-01 -8.79510897e-02 -2.52988032e-02
3.35964474e-01 1.61923110e-01 -2.74530011e-01 -3.02797997e-01
-1.24392597e-01 -1.43385822e-01]
[-4.82757788e-01 -1.95209510e-01 -9.75272037e-02 7.12350167e-02
5.28178564e-01 -5.04439796e-02 1.14219176e-01 -3.76742485e-02
2.69787265e-01 -3.33139225e-01]
[-2.72416169e-02 -1.00506809e-01 -1.26912214e-01 1.27953887e-01
-6.47147934e-02 3.08431187e-02 2.95194570e-01 2.69759813e-03
2.61893900e-01 -2.01156459e-01]
[6.57118828e-02 -2.29742168e-01 4.15592843e-02 1.35996986e-01
1.16327942e-01 1.84340473e-01 -1.68702147e-01 -1.12678411e-01
-9.12124294e-02 1.37453341e-02]
[3.40728284e-01 -1.44506417e-01 8.91879613e-02 8.56337010e-02
3.23309182e-01 7.74000251e-02 -1.97393277e-01 9.54864586e-02
-2.92551739e-01 1.01855054e-01]
[1.05351595e-01 -7.16353646e-02 1.32855108e-02 -7.72796326e-03
-8.14441098e-02 -4.24241716e-02 2.13489552e-01 7.87848916e-02
5.21261329e-02 1.39758617e-01]
[-1.53171216e-02 1.76714655e-01 2.12857884e-01 -3.16470605e-01
3.76336058e-02 -6.29457286e-02 -3.54712732e-02 -2.06474571e-01
1.45526393e-02 -7.70130675e-02]
[-1.99142845e-01 -4.80428201e-01 -7.49727859e-02 1.93777098e-02
3.60236091e-01 -3.55770517e-02 -3.52235204e-01 -5.41895522e-02
-1.11507653e-01 4.45106381e-02]
[-4.15948560e-02 -2.65327318e-01 -8.34684623e-02 1.72323038e-01
2.40075273e-01 -1.24099976e-02 -1.38367952e-01 1.57793523e-01
-2.28935145e-01 -4.41764195e-02]
[-3.37537467e-01 -3.51731783e-02 -1.82013273e-01 2.69359189e-01
4.18650150e-01 8.08680260e-02 2.25801097e-01 5.85068821e-02
6.70152172e-02 -2.79478101e-01]
[-2.23741212e-01 -1.99366456e-01 -5.78048803e-02 -2.81855281e-02
1.46295009e-01 1.55205365e-01 2.54648863e-01 3.91158234e-02
2.02173872e-01 -2.59628755e-01]
[-1.34497974e-01 4.05937186e-02 -1.85282318e-01 1.79897332e-01
-8.04907538e-04 8.02930973e-02 -2.90587002e-01 3.16549819e-02
1.39254833e-01 -3.91004590e-02]
[2.03064568e-01 -1.55884313e-01 -1.67569036e-01 -1.15195879e-01

7.45910809e-01	4.32162771e-05	-2.60148757e-01	-1.92167930e-01
-2.61074468e-01	1.57873059e-01]		
[6.51465111e-02	-1.03011244e-01	9.32725418e-02	1.28125153e-01
-4.66862796e-02	-2.04487204e-02	1.61449584e-01	1.10958814e-01
1.01275014e-01	-1.66112533e-01]		
[6.13481735e-02	6.65062990e-02	5.13508496e-02	1.58933815e-02
1.45641179e-01	-1.16946387e-01	8.96976382e-02	7.44339155e-02
-1.07698258e-01	-1.04104183e-01]		
[-1.75295130e-01	-1.46036614e-01	-6.68573651e-02	-1.51821430e-01
2.89538200e-01	-2.32900923e-01	2.43035906e-02	-2.44148228e-01
-2.40102333e-02	5.11900525e-03]		
[7.14551357e-02	-1.59689893e-01	-1.48210764e-01	-5.87607712e-02
4.31222325e-03	-2.15671876e-01	-3.88695928e-01	4.47444926e-02
-3.20431262e-01	1.99165892e-01]		
[1.97621466e-02	1.01514100e-01	1.72128213e-01	8.76767686e-02
-2.94047928e-01	7.12414335e-02	-3.14896427e-03	1.83502411e-02
2.88957844e-01	-1.32521353e-01]		
[-4.30808485e-01	-1.21640168e-01	-1.85613848e-01	-2.43109961e-02
1.54910537e-01	5.13066597e-02	2.43563298e-01	3.47867188e-02
2.09680070e-01	-2.78676150e-01]		
[-8.29006551e-02	-1.00959200e-01	2.09626596e-02	-8.45575112e-02
5.80243784e-01	1.16090874e-01	-9.31316867e-02	-9.32753317e-02
-1.67794548e-01	-1.47100691e-01]		
[1.08970512e-01	-2.25507075e-01	-8.15255966e-02	-9.47355137e-02
1.58028098e-01	-4.75223265e-02	-2.44297881e-01	4.29639332e-02
-1.16385267e-01	8.97794084e-02]		
[6.08939959e-03	5.23736055e-02	1.09433343e-01	4.98571463e-02
-5.34429088e-02	-6.86243989e-02	-2.50533113e-01	4.25701013e-02
-3.57740051e-02	-6.01152177e-02]		
[-1.87974550e-02	1.32180163e-01	3.09344242e-02	2.93567304e-02
-6.66656238e-02	1.06382322e-02	-7.20617483e-02	-1.51684539e-02
1.05130658e-01	-2.03619546e-01]		
[-6.42541078e-02	1.65006458e-01	-8.38815175e-02	-7.31764416e-03
-3.18520096e-01	1.83914489e-01	1.37600095e-01	1.87645833e-03
-4.38667776e-02	1.73728972e-01]		
[2.39163031e-01	8.51145017e-02	-1.57704947e-01	2.18465075e-01
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-2.38292174e-01	3.24080036e-01]		
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-2.34938539e-02 1.53111018e-01]
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```

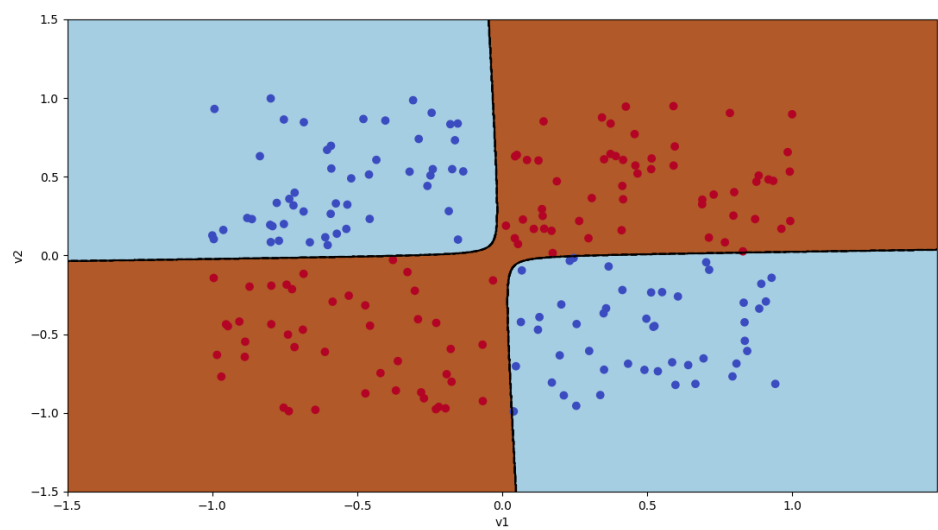
Accuracy: 98.88%

Question 2:

Polynomial Kernel

C	d	Accuracy	Std Dev
1	2	0.9613333333	0.0106405931
1	3	0.4271666667	0.0279190298
1	4	0.8025	0.0288024883
10	2	0.965	0.0028867513
10	3	0.4476666667	0.0352073225
10	4	0.894	0.0208726296
100	2	0.9741666667	0.002608746
100	3	0.475	0.026894857
100	4	0.9313333333	0.0149406232
1000	2	0.9761666667	0.0038042374
1000	3	0.463	0.0269752973
1000	4	0.9483333333	0.002981424
10000	2	0.9846666667	0.0042687495
10000	3	0.478	0.0291147156
10000	4	0.957	0.0035590261

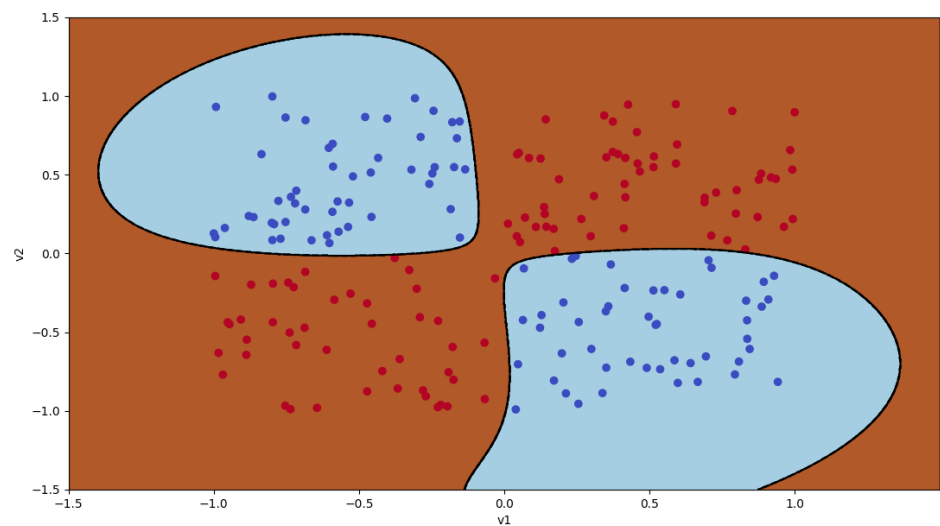
Plotting graph for C=10000, d=2



RBF Kernel

C	Sigma	Accuracy	Std-Dev
1	2	0.9563333333	0.0097410928
1	3	0.9591666667	0.0084738159
1	4	0.9585	0.0121894763
10	2	0.9681666667	0.0035316034
10	3	0.9675	0.0047871355
10	4	0.9678333333	0.0051126206
100	2	0.9783333333	0.0048876261
100	3	0.9793333333	0.0054365021
100	4	0.9785	0.0050249378
1000	2	0.9658333333	0.0063355259
1000	3	0.9641666667	0.0054898897
1000	4	0.9645	0.0062383224
10000	2	0.9783333333	0.0058214164
10000	3	0.9766666667	0.0072264945
10000	4	0.9765	0.0068495742

Plotting graph for C=10000, gamma=2



Question 3:

Summary of data:

Column Code	Description	Average	Std-dev
AAGE	AGE	34.4941986638	22.310839296
AHRSPAY	Wages	55.426908176	274.895765018
CAPGAIN	Capital-Gain	434.718989791	4697.51950779
CAPLOSS	Capital-Loss	37.3137883853	271.895746998
WKSWORK	Weeks-Worked-In-Year	23.1748971297	24.4114269928

Dealing with Real attributes:

Added relevant continuous attributes(WAGE,CAPGAIN,CAPLOSS) with binning. No of bins decided based on distinct values present for that Attribute.

```
data["WAGE_BIN"] = pd.cut(data.AHRSPAY, bins=1000, labels=False)
categorical_attributes.insert(0, "WAGE_BIN")

data["CAPGAIN_BIN"] = pd.cut(data.CAPGAIN, bins=132, labels=False)
categorical_attributes.insert(0, "CAPGAIN_BIN")

data["CAPLOSS_BIN"] = pd.cut(data.CAPLOSS, bins=113, labels=False)
categorical_attributes.insert(0, "CAPLOSS_BIN")
```

Handling missing entries:

Missing values are only present in categorical attributes and each such attribute with missing values has one particular value which is very dominantly occurring for that attribute. So the missing value has been replaced by the mode for that attribute.

Average Accuracy: 77.16

Std-Dev: 0.0092