

## E5179:Deep Learning for Imaging Programming

### Assignment 1: MNIST Classification using MLP

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#### Base Model

#### STEPS:

- Downloading MNIST datasets
- Initialization of parameters
- Activation Function
- Forwards propagation
- Backward propagation
- Updata parameters
- Cost Function
- Accuracy and Confusion matrix
- Training and Testing loss

#### Visualization of images with their labels.

Index: 0  
Label: 5



Index: 1  
Label: 0



Index: 2  
Label: 4



Index: 3  
Label: 1



Index: 4  
Label: 9



Index: 5  
Label: 2



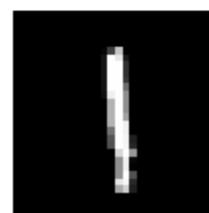
Index: 6  
Label: 1



Index: 7  
Label: 3



Index: 8  
Label: 1



Index: 9  
Label: 4



## CASE 1

learning\_rate = 0.01

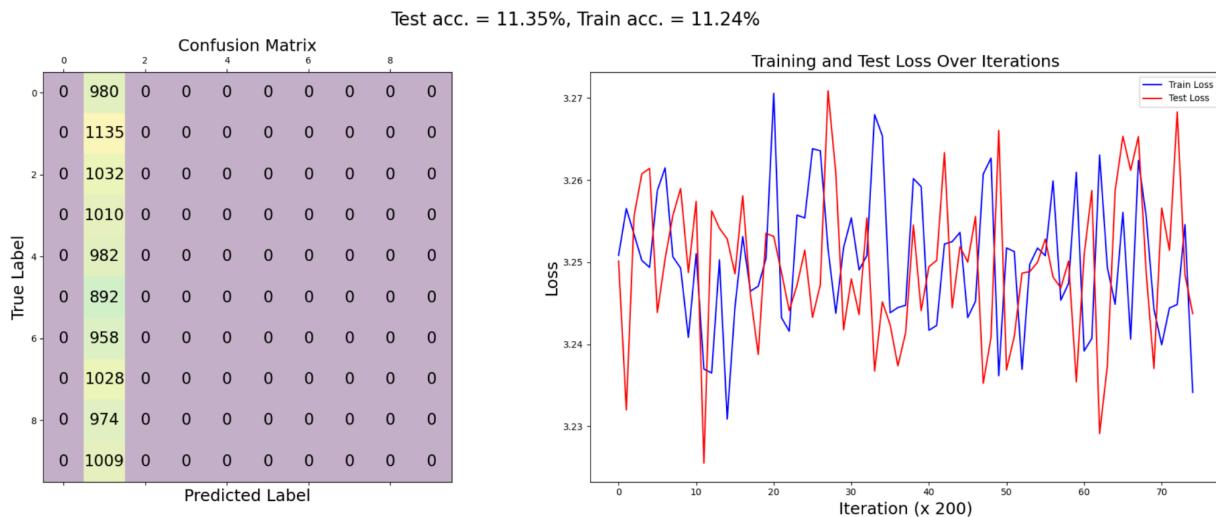
lambd = 0

epoch = 15

batch\_size = 64

initial = "zero" - weights

Model Key: Epoch=15, alpha=0.01, Regularization=0, Batch=64, Initialization=zero  
Cost after epoch 0, iteration 0: Train Cost: 3.250829733914482, Test Cost: 3.2501445954240697  
Cost after epoch 0, iteration 200: Train Cost: 3.2565329875540816, Test Cost: 3.2319978981871307  
Cost after epoch 0, iteration 400: Train Cost: 3.25339618727332, Test Cost: 3.255656229483162  
Cost after epoch 0, iteration 600: Train Cost: 3.2502085364189286, Test Cost: 3.260764734994694  
Cost after epoch 0, iteration 800: Train Cost: 3.249378139533564, Test Cost: 3.261425518027011  
Cost after epoch 1, iteration 0: Train Cost: 3.2587339809720453, Test Cost: 3.2438677564201277  
Cost after epoch 1, iteration 200: Train Cost: 3.261504600220028, Test Cost: 3.2503987476564458  
Cost after epoch 1, iteration 400: Train Cost: 3.2506611852155576, Test Cost: 3.255694773104604  
Cost after epoch 1, iteration 600: Train Cost: 3.2492749719657006, Test Cost: 3.2589763293863605  
Cost after epoch 1, iteration 800: Train Cost: 3.240837990512092, Test Cost: 3.2487539761731843  
Cost after epoch 2, iteration 0: Train Cost: 3.2510219206202167, Test Cost: 3.257418368611275  
Cost after epoch 2, iteration 200: Train Cost: 3.2369782424003755, Test Cost: 3.2255139789707465  
Cost after epoch 2, iteration 400: Train Cost: 3.2365079589847077, Test Cost: 3.2562546758047715  
Cost after epoch 2, iteration 600: Train Cost: 3.2502773810978045, Test Cost: 3.2541379596164264



## CASE 2

learning\_rate = 0.01

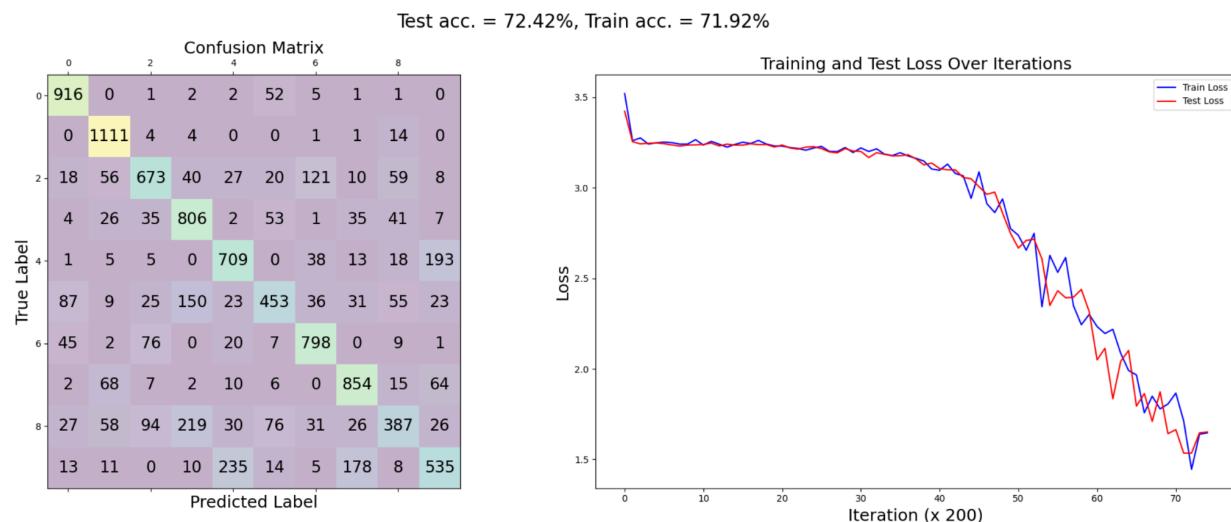
lambd = 0

epoch = 15

batch\_size = 64

initial = "random"

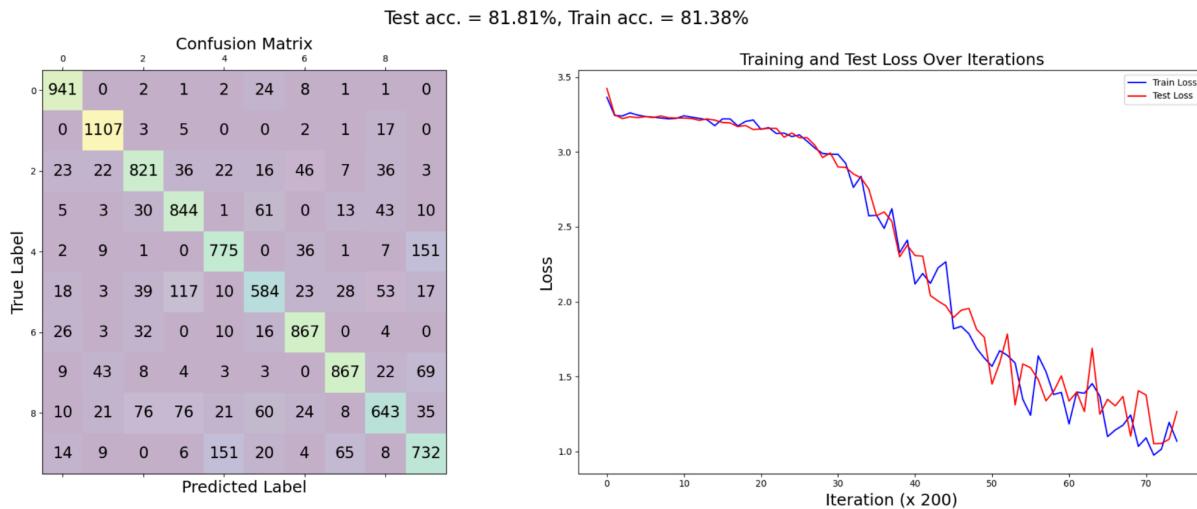
```
Model Key: Epoch=15,alpha=0.01,Regularization=0,Batch=64,Initilization=random
Cost after epoch 0, iteration 0: Train Cost: 3.519360144013942, Test Cost: 3.421410931096408
Cost after epoch 0, iteration 200: Train Cost: 3.2592092895664875, Test Cost: 3.2535988834490084
Cost after epoch 0, iteration 400: Train Cost: 3.2743739861694334, Test Cost: 3.2414804591279838
Cost after epoch 0, iteration 600: Train Cost: 3.240629678421011, Test Cost: 3.2448357055564876
Cost after epoch 0, iteration 800: Train Cost: 3.247208632769028, Test Cost: 3.2466694616005864
Cost after epoch 1, iteration 0: Train Cost: 3.251322893857357, Test Cost: 3.242677470297336
Cost after epoch 1, iteration 200: Train Cost: 3.248305123739125, Test Cost: 3.23560716561706
Cost after epoch 1, iteration 400: Train Cost: 3.2402493965780113, Test Cost: 3.2294770894299556
Cost after epoch 1, iteration 600: Train Cost: 3.2403541162958276, Test Cost: 3.2349667942985203
Cost after epoch 1, iteration 800: Train Cost: 3.2649508866171786, Test Cost: 3.236242559668683
Cost after epoch 2, iteration 0: Train Cost: 3.2351723504900116, Test Cost: 3.238365977953752
Cost after epoch 2, iteration 200: Train Cost: 3.255519698991239, Test Cost: 3.245907510260862
Cost after epoch 2, iteration 400: Train Cost: 3.2400170213512696, Test Cost: 3.2301829000912874
Cost after epoch 2, iteration 600: Train Cost: 3.2236533755368066, Test Cost: 3.240229997214773
Cost after epoch 2, iteration 800: Train Cost: 3.2384612170484663, Test Cost: 3.2348037666398035
Cost after epoch 3, iteration 0: Train Cost: 3.250774829401215, Test Cost: 3.2348234745445215
Cost after epoch 3, iteration 200: Train Cost: 3.243591663732648, Test Cost: 3.242122468991555
```



## CASE 3

```
learning_rate = 0.01
lambda = 0
epoch = 15
batch_size = 64
initial = "glorot"
```

Model Key: Epoch=15, alpha=0.01, Regularization=0, Batch=64, Initialization=glorot  
Cost after epoch 0, iteration 0: Train Cost: 3.364798570254992, Test Cost: 3.4234719927068054  
Cost after epoch 0, iteration 200: Train Cost: 3.243369220322021, Test Cost: 3.248316170407343  
Cost after epoch 0, iteration 400: Train Cost: 3.239952774484645, Test Cost: 3.2231276027637827  
Cost after epoch 0, iteration 600: Train Cost: 3.260996398545833, Test Cost: 3.2348077026819415  
Cost after epoch 0, iteration 800: Train Cost: 3.2458382898675375, Test Cost: 3.22923214283201  
Cost after epoch 1, iteration 0: Train Cost: 3.236380140797255, Test Cost: 3.235467781342831  
Cost after epoch 1, iteration 200: Train Cost: 3.2324376071011782, Test Cost: 3.2294144020777233  
Cost after epoch 1, iteration 400: Train Cost: 3.226601522035077, Test Cost: 3.2403583921036274  
Cost after epoch 1, iteration 600: Train Cost: 3.2205031569197335, Test Cost: 3.2279088112222136  
Cost after epoch 1, iteration 800: Train Cost: 3.2238699755178204, Test Cost: 3.226511487525244  
Cost after epoch 2, iteration 0: Train Cost: 3.2414518167961512, Test Cost: 3.226224207715169  
Cost after epoch 2, iteration 200: Train Cost: 3.2321656846832334, Test Cost: 3.222861510903453  
Cost after epoch 2, iteration 400: Train Cost: 3.2239726115364276, Test Cost: 3.211186996581196  
Cost after epoch 2, iteration 600: Train Cost: 3.2150790699035756, Test Cost: 3.2206302816917365  
Cost after epoch 2, iteration 800: Train Cost: 3.175178192896444, Test Cost: 3.2124383012472233  
Cost after epoch 3, iteration 0: Train Cost: 3.220662568149917, Test Cost: 3.1967830746337897  
Cost after epoch 3, iteration 200: Train Cost: 3.220254106918895, Test Cost: 3.193959414262962  
Cost after epoch 3, iteration 400: Train Cost: 3.172929211916992, Test Cost: 3.1690235074049964



## Base model with ReLU as activation function

### CASE 1

learning\_rate = 0.01

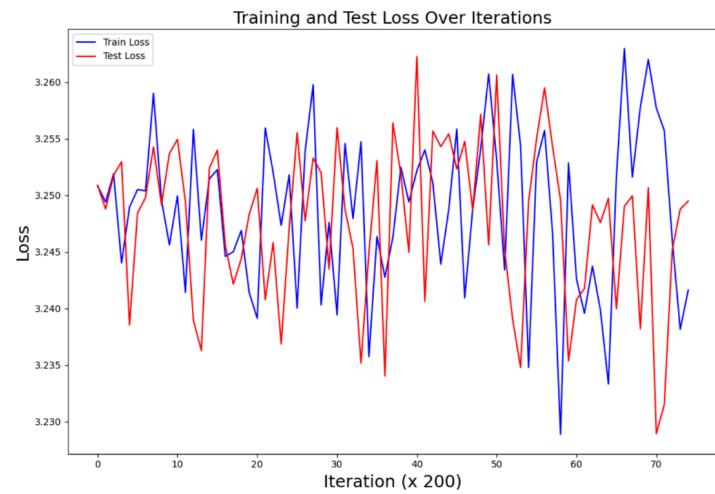
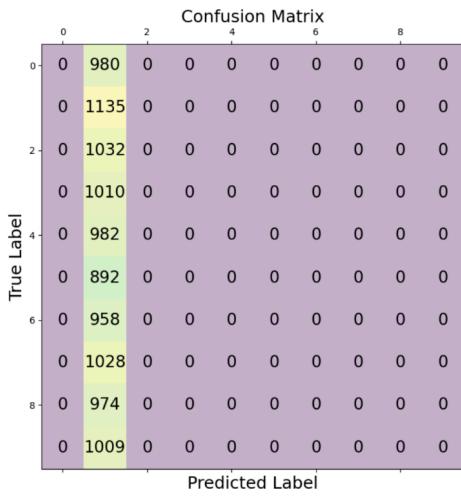
lambd = 0

epoch = 15

batch\_size = 64

initial = "zero"

Test acc. = 11.35%, Train acc. = 11.24%



### CASE 2

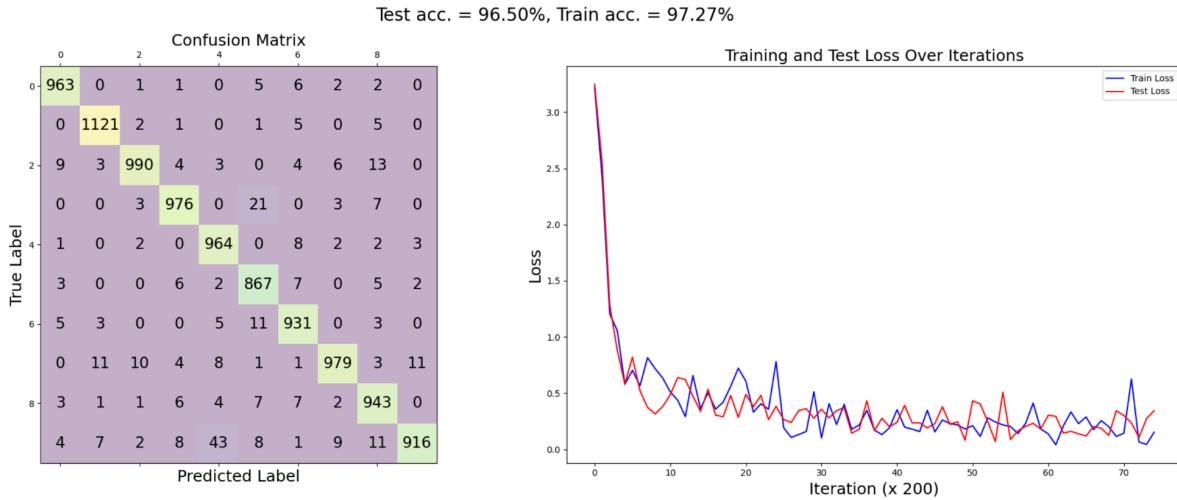
learning\_rate = 0.01

lambd = 0

epoch = 15

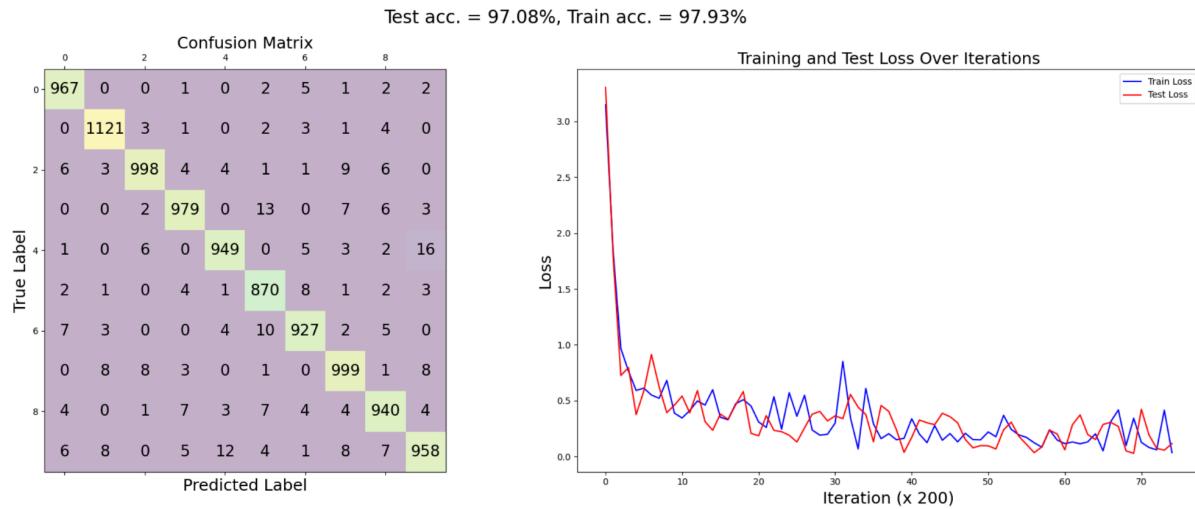
batch\_size = 64

initial = "random"



### CASE 3

learning\_rate = 0.01  
 lambd = 0  
 epoch = 15  
 batch\_size = 64  
 initial = "glorot"



### Base model with tanh as activation function

## CASE 1

learning\_rate = 0.01

lambd = 0

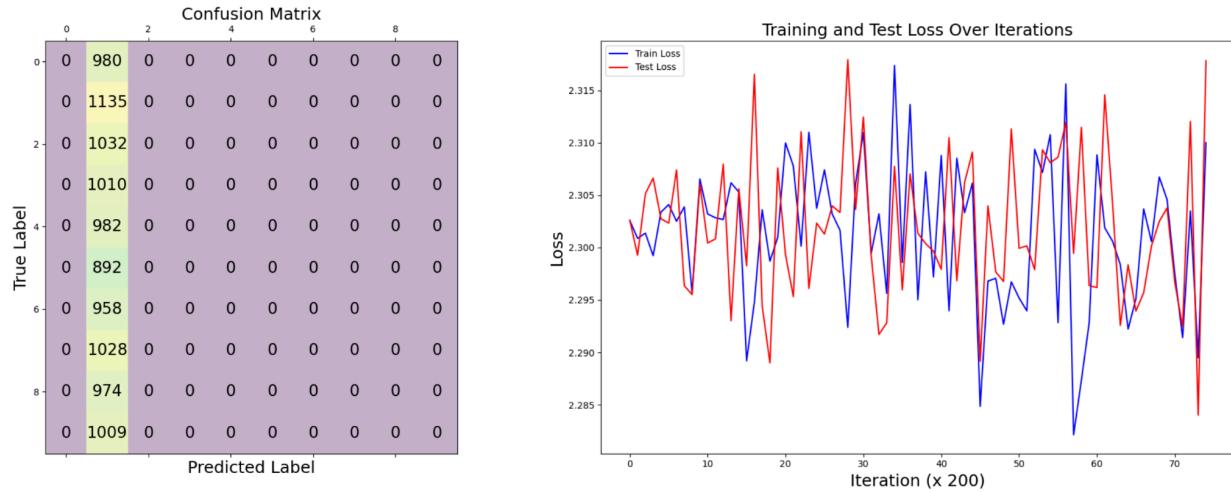
epoch = 15

batch\_size = 64

initial = "zero"

```
Model Key: Epoch=15,alpha=0.01,Regularization=0,Batch=64,Initialization=zero
Cost after epoch 0, iteration 0: Train Cost: 2.3025850929940455, Test Cost: 2.302615899151456
Cost after epoch 0, iteration 200: Train Cost: 2.300873768295059, Test Cost: 2.2992693474220554
Cost after epoch 0, iteration 400: Train Cost: 2.3013808147462433, Test Cost: 2.305132668242764
Cost after epoch 0, iteration 600: Train Cost: 2.299218592730832, Test Cost: 2.306633091715613
Cost after epoch 0, iteration 800: Train Cost: 2.303380887710829, Test Cost: 2.3027442342667914
Cost after epoch 1, iteration 0: Train Cost: 2.304105200870981, Test Cost: 2.302342232258721
Cost after epoch 1, iteration 200: Train Cost: 2.3025125842634337, Test Cost: 2.307397361934574
Cost after epoch 1, iteration 400: Train Cost: 2.3038835123980665, Test Cost: 2.2963623951789374
Cost after epoch 1, iteration 600: Train Cost: 2.2957127574363985, Test Cost: 2.295517118552441
Cost after epoch 1, iteration 800: Train Cost: 2.3065381739559534, Test Cost: 2.306064417937886
Cost after epoch 2, iteration 0: Train Cost: 2.3032111120130456, Test Cost: 2.30043912206932
Cost after epoch 2, iteration 200: Train Cost: 2.3028412334212556, Test Cost: 2.3008324130028495
Cost after epoch 2, iteration 400: Train Cost: 2.3026754594360366, Test Cost: 2.307970320528043
Cost after epoch 2, iteration 600: Train Cost: 2.306183782993075, Test Cost: 2.2930239946927684
Cost after epoch 2, iteration 800: Train Cost: 2.3052988692213088, Test Cost: 2.3056210691601393
```

Test acc. = 11.35%, Train acc. = 11.24%



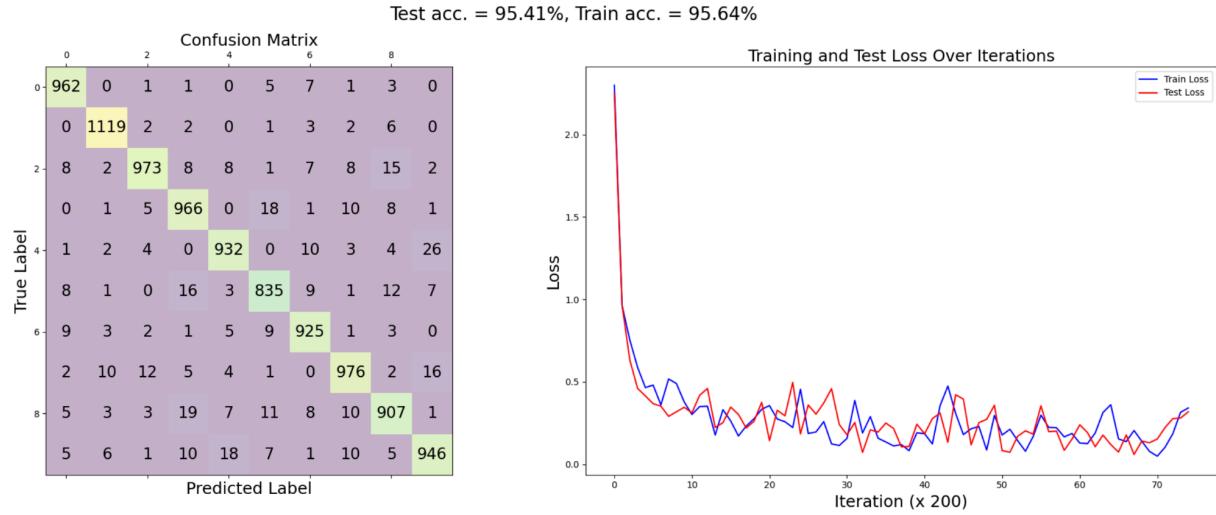
## CASE 2

learning\_rate = 0.01

lambd = 0  
 epoch = 15  
 batch\_size = 64  
 initial = "random"

```

Model Key: Epoch=15,alpha=0.01,Regularization=0,Batch=64,Initialization=random
Cost after epoch 0, iteration 0: Train Cost: 2.299490621790012, Test Cost: 2.249361357131885
Cost after epoch 0, iteration 200: Train Cost: 0.9619640599176462, Test Cost: 0.963802939966268
Cost after epoch 0, iteration 400: Train Cost: 0.7531023651961821, Test Cost: 0.631168952783942
Cost after epoch 0, iteration 600: Train Cost: 0.5872091773964412, Test Cost: 0.4597131639715725
Cost after epoch 0, iteration 800: Train Cost: 0.46487822468113765, Test Cost: 0.4142676025264681
Cost after epoch 1, iteration 0: Train Cost: 0.4799072757315818, Test Cost: 0.3672176341710244
Cost after epoch 1, iteration 200: Train Cost: 0.3600640954258434, Test Cost: 0.3518914588639778
Cost after epoch 1, iteration 400: Train Cost: 0.5171792036145257, Test Cost: 0.29038572098283294
Cost after epoch 1, iteration 600: Train Cost: 0.4895562544127641, Test Cost: 0.31786042401745185
Cost after epoch 1, iteration 800: Train Cost: 0.37846450151691596, Test Cost: 0.3454809905330553
Cost after epoch 2, iteration 0: Train Cost: 0.30153244918016664, Test Cost: 0.31142326144881516
Cost after epoch 2, iteration 200: Train Cost: 0.349683487399958, Test Cost: 0.4185687483552999
Cost after epoch 2, iteration 400: Train Cost: 0.3516677795866071, Test Cost: 0.4593845094045558
Cost after epoch 2, iteration 600: Train Cost: 0.1772396593196529, Test Cost: 0.2230618292313405
Cost after epoch 2, iteration 800: Train Cost: 0.33046677384594925, Test Cost: 0.2517309441915472
Cost after epoch 3, iteration 0: Train Cost: 0.26231410983496406, Test Cost: 0.34650726946402316
  
```

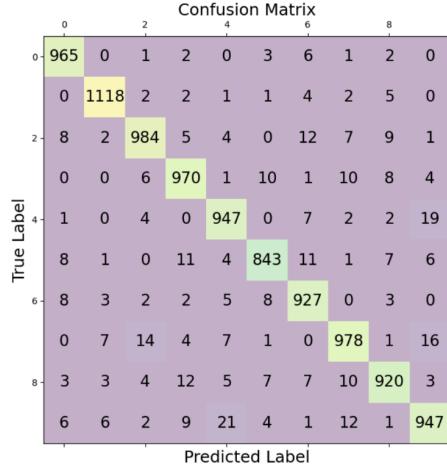


## CASE 3

```
learning_rate = 0.01
lambd = 0
epoch = 15
batch_size = 64
initial = "glorot"
```

Model Key: Epoch=15,alpha=0.01,Regularization=0,Batch=64,Initialization=glorot  
Cost after epoch 0, iteration 0: Train Cost: 2.402181451199647, Test Cost: 2.3645243826247904  
Cost after epoch 0, iteration 200: Train Cost: 0.7597189753021367, Test Cost: 0.5572789436109884  
Cost after epoch 0, iteration 400: Train Cost: 0.5009029235565605, Test Cost: 0.6109102424467863  
Cost after epoch 0, iteration 600: Train Cost: 0.427422233175055, Test Cost: 0.48549954100404563  
Cost after epoch 0, iteration 800: Train Cost: 0.38994489518285935, Test Cost: 0.44814707390401853  
Cost after epoch 1, iteration 0: Train Cost: 0.4826853395253341, Test Cost: 0.33704153122526076  
Cost after epoch 1, iteration 200: Train Cost: 0.44253956101279707, Test Cost: 0.14304370551590784  
Cost after epoch 1, iteration 400: Train Cost: 0.2425591228097011, Test Cost: 0.4103089967750817  
Cost after epoch 1, iteration 600: Train Cost: 0.2964783136875335, Test Cost: 0.26415471638625  
Cost after epoch 1, iteration 800: Train Cost: 0.47316717557677773, Test Cost: 0.4737646544884463  
Cost after epoch 2, iteration 0: Train Cost: 0.31883396369486156, Test Cost: 0.21605806675366757  
Cost after epoch 2, iteration 200: Train Cost: 0.33098906570317876, Test Cost: 0.29335632661406735  
Cost after epoch 2, iteration 400: Train Cost: 0.49820865500600425, Test Cost: 0.2731458905792682  
Cost after epoch 2, iteration 600: Train Cost: 0.4735931939065407, Test Cost: 0.3234665225359433  
Cost after epoch 2, iteration 800: Train Cost: 0.19637426103510758, Test Cost: 0.27475221601734456  
Cost after epoch 3, iteration 0: Train Cost: 0.25428618986432244, Test Cost: 0.33713965440963806  
Cost after epoch 3, iteration 200: Train Cost: 0.10418063004790451, Test Cost: 0.22579109532301594  
Cost after epoch 3, iteration 400: Train Cost: 0.26636177102013947, Test Cost: 0.30958830633204537

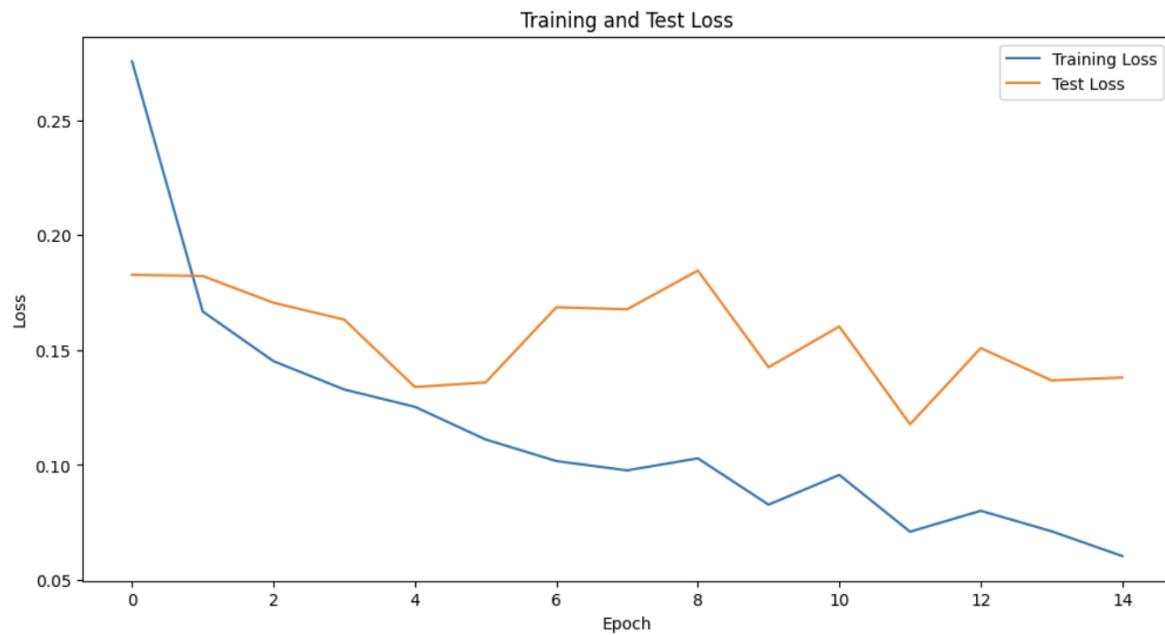
Test acc. = 95.99%, Train acc. = 96.49%

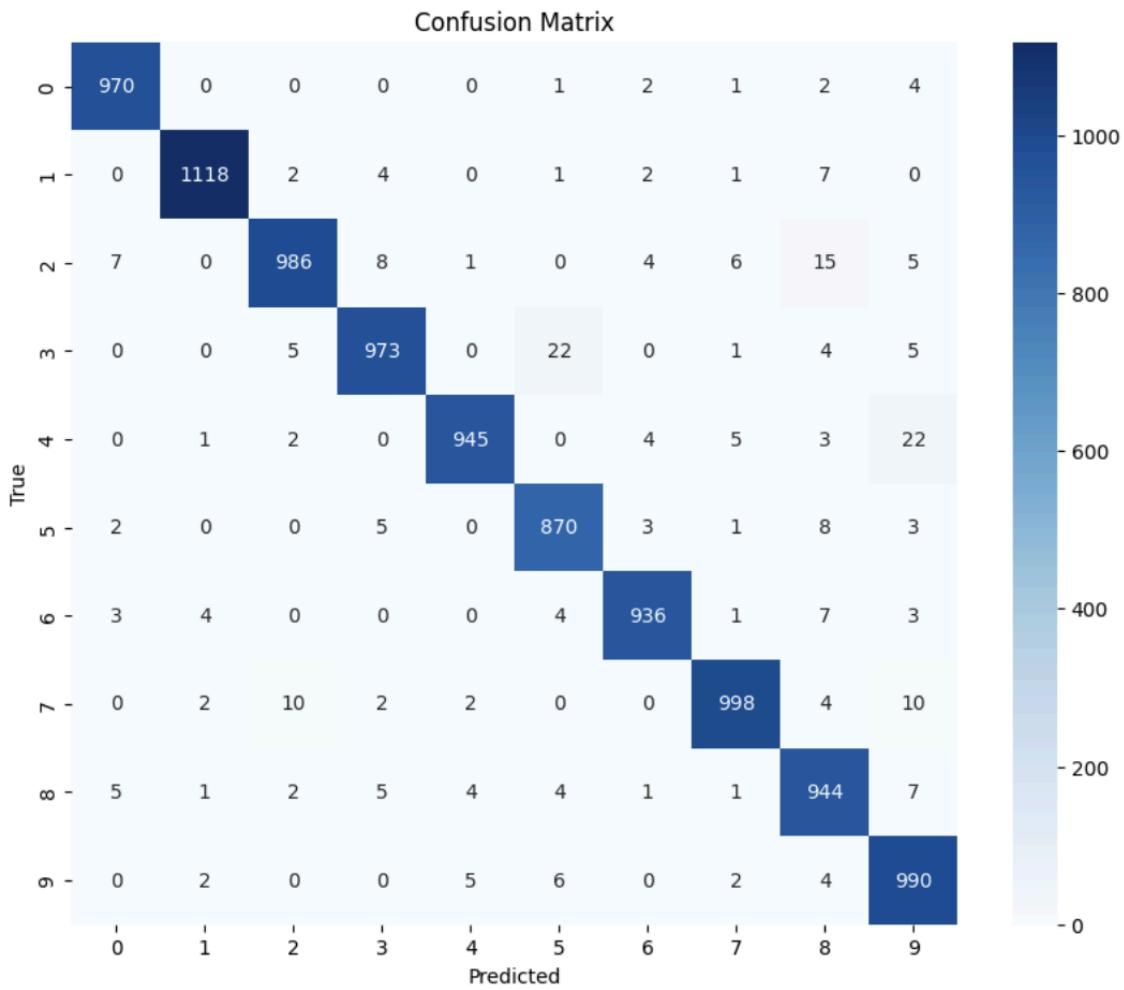


## USING PYTORCH

Test Accuracy: 97.30%

Training Accuracy: 98.86%





## USING L2 REGULARIZATION

Test Accuracy: 95.13%

Training Accuracy: 95.22%

