# CSE472: Machine Learning

Offline 3: Feed-forward Neural Network

Date: 3 January 2024

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# Hyperparameters:

- 1. Epochs
- 2. Batch Size
- 3. Learning Rate
- 4. Adam Optimizer:

a. Beta1: 0.9b. Beta2: 0.999

c. Epsilon: 1E-8

# Model 1:

### **Architecture:**

DenseLayer(784, 512),

ReLU(),

DropoutLayer(0.5),

DenseLayer(512, 128),

ReLU(),

DropoutLayer(0.25),

DenseLayer(128, 64),

ReLU(),

DenseLayer(64, 26),

Softmax()

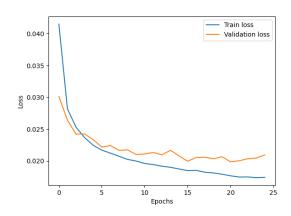
### Hyperparameters:

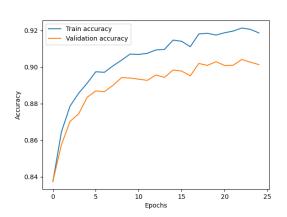
Epochs: 25

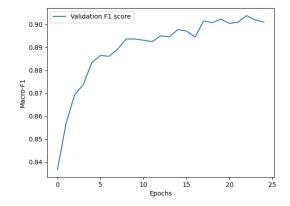
Batch Size: 256

Learning rate: 0.005

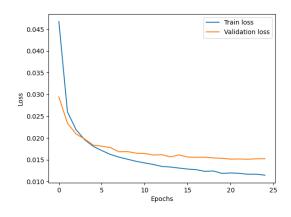
Training Accuracy: 0.9186368778280543 Validation Accuracy: 0.9013354700854701 Validation F1 score: 0.900996605092391

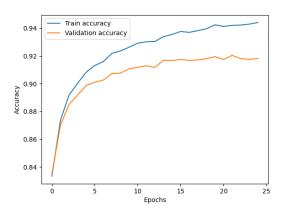


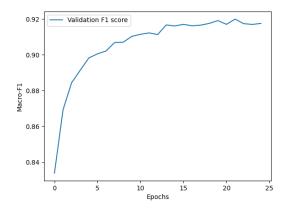




Training Accuracy: 0.9441365007541478 Validation Accuracy: 0.9181623931623931 Validation F1 score: 0.917484849884212

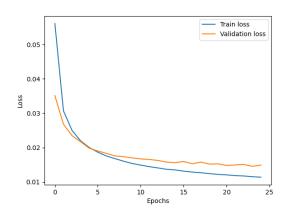


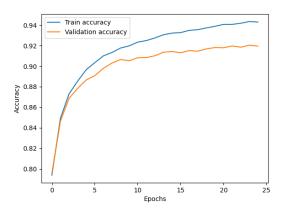


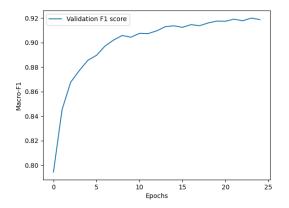


Training Accuracy: 0.9429487179487179 Validation Accuracy: 0.9194978632478632

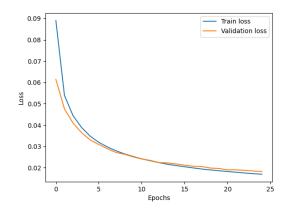
Validation F1 score: 0.9187430319379778 (Best F1 Score)

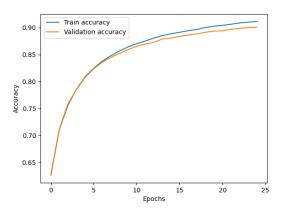


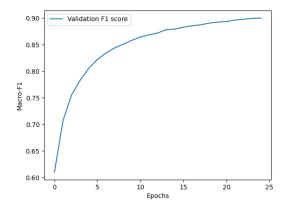




Training Accuracy: 0.9112085218702866 Validation Accuracy: 0.9005876068376069 Validation F1 score: 0.9000456710896209







# Model 2:

### **Architecture:**

DenseLayer(784, 128),

ReLU(),

DropoutLayer(0.5),

DenseLayer(128, 32),

ReLU(),

DenseLayer(32, 26),

Softmax()

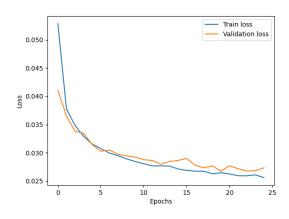
### Hyperparameters:

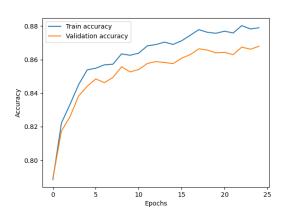
Epochs: 25

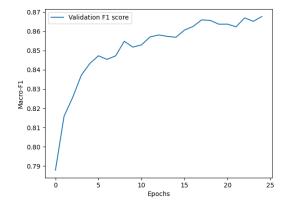
Batch Size: 256

Learning rate: 0.005

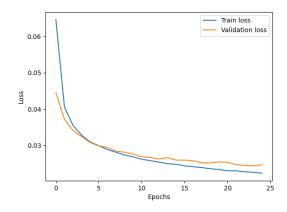
Training Accuracy: 0.878987556561086 Validation Accuracy: 0.867948717948718 Validation F1 score: 0.8676702518628798

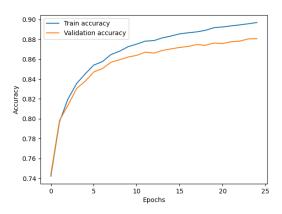


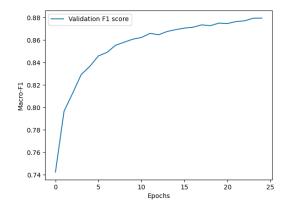




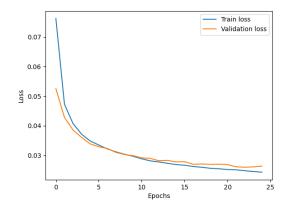
Training Accuracy: 0.8968608597285068 Validation Accuracy: 0.8806089743589743 **Validation F1 score: 0.8795661373558642** 

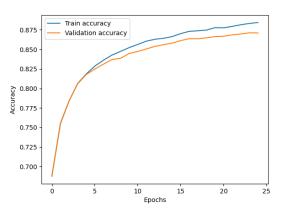


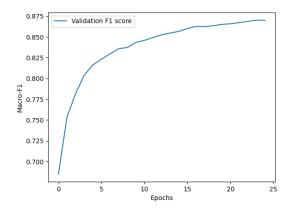




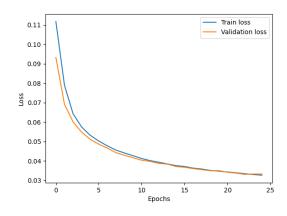
Training Accuracy: 0.8843891402714932 Validation Accuracy: 0.8709935897435898 Validation F1 score: 0.8700275575123337

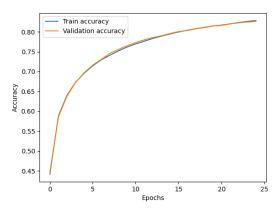


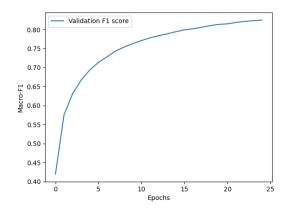




Training Accuracy: 0.8284879336349925 Validation Accuracy: 0.826068376068376 Validation F1 score: 0.8249093780693262







# Model 3:

### **Architecture:**

DenseLayer(784, 128),

ReLU(),

DropoutLayer(0.5),

DenseLayer(128, 128),

ReLU(),

DropoutLayer(0.5),

DenseLayer(128, 64),

ReLU(),

DropoutLayer(0.5),

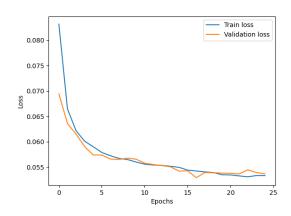
DenseLayer(64, 26),

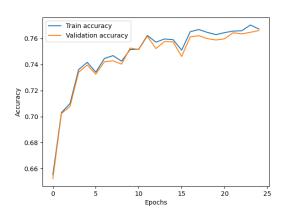
Softmax()

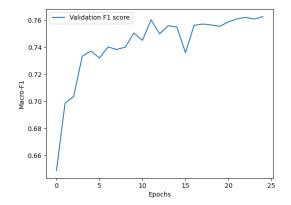
### Hyperparameters:

Epochs: 25 Batch Size: 256 Learning rate: 0.005

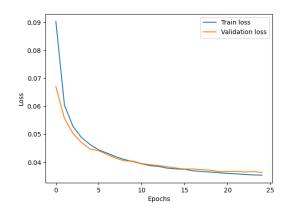
> Training Accuracy: 0.7672888386123681 Validation Accuracy: 0.7661324786324787 Validation F1 score: 0.7625766354029706

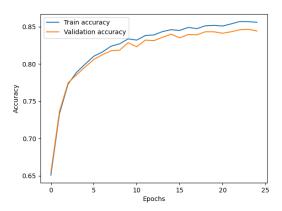


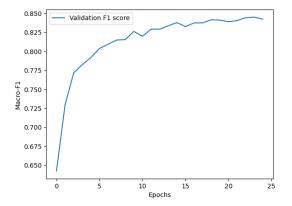




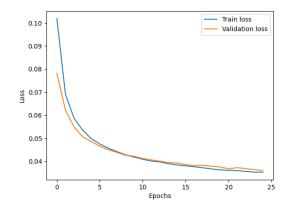
Training Accuracy: 0.8558257918552036 Validation Accuracy: 0.8441773504273504 Validation F1 score: 0.842437551432689

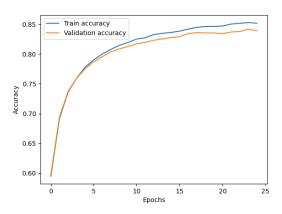


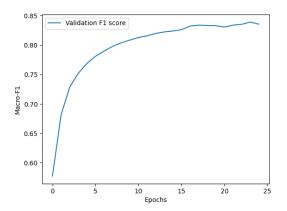




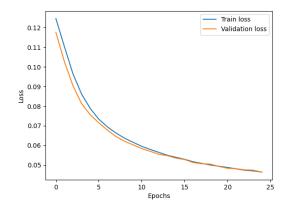
Training Accuracy: 0.8517816742081448
Validation Accuracy: 0.8391559829059829
Validation F1 score: 0.8356123920580967

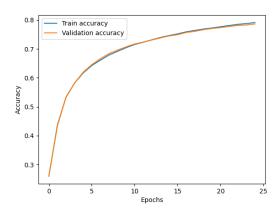


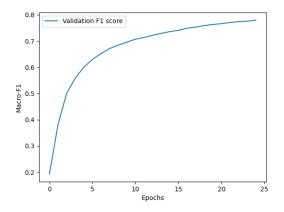




Training Accuracy: 0.7911953242835595 Validation Accuracy: 0.7862179487179487 Validation F1 score: 0.7798927919642318







# Best F1 score:

## Model 1 with learning rate 0.0005

Validation F1 score: 0.9187430319379778

### **Independent Test Dataset Results:**

Accuracy: 0.9152403846153846 F1 score: 0.9148286294239791

### Confusion Matrix:

∢ -	747	3	1	7	2	1	5	7	0	1	2	0	2	2	5	4	5	0	0	0	2	0	0	1	0	3
ω-	1	762	0	4	2	0	3	13	0	1	0	2	0	1	2	0	2	3	0	0	0	0	0	0	0	4
<b>u</b> -	1	1	751	2	24	0	1	0	0	0	1	5	0	0	3	0	2	4	0	2	2	0	1	0	0	0
۵ -	5	7	0	749	0	0	0	1	0	2	0	0	1	3	23	5	0	1	0	0	2	0	0	0	1	0
ш-	2	5	9	0	758	4	1	0	1	0	0	2	0	0	1	5	1	2	0	5	1	0	0	2	0	1
և -	0	0	0	1	2	736	4	0	2	0	0	1	0	0	0	22	0	4	2	25	0	0	0	0	0	1
<b>o</b> -	18	16	5	2	2	5	621	0	0	7	0	0	0	1	2	1	111	0	5	0	1	0	0	0	3	0
Ι-	2	8	0	2	0	0	0	758	0	0	3	8	3	10	0	0	0	1	0	0	2	0	2	1	0	0
	0	1	1	2	1	1	1	0	503	17	0	259	0	0	0	0	0	1	2	0	0	1	1	1	0	8
	0	3	0	8	1	0	3	0	16	737	0	7	0	0	0	0	1	0	4	14	2	0	0	0	3	1
⊻ -	1	4	1	1	1	4	0	13	0	0	742	6	0	3	0	0	0	4	0	5	0	1	0	12	2	0
- ب	0	2	6	0	0	0	0	5	106	1	0	677	0	0	0	0	1	0	0	0	0	0	0	0	2	0
<u>-</u> Σ -	1	0	0	1	0	0	0	4	0	0	1	0	776	12	0	0	0	0	0	1	2	0	1	0	1	0
Actual N M	11	1	0	5	0	0	0	16	0	1	4	0	12	733	0	0	0	3	0	0	2	3	5	3	1	0
0 -	2	0	1	20	0	0	1	0	0	0	0	0	0	2	768	1	3	0	0	0	2	0	0	0	0	0
- ۵	1	1	0	6	1	4	1	0	0	0	0	0	0	2	0	779	1	2	0	1	0	1	0	0	0	0
o -	35	2	0	6	2	6	74	0	1	1	1	1	0	1	10	6	642	0	1	2	3	1	1	0	2	2
∝ -	8	2	2	0	3	4	0	0	1	0	5	1	1	2	0	4	0	732	1	8	0	11	0	3	8	4
v -	3	2	1	0	0	1	12	1	1	16	0	0	0	1	0	0	1	1	760	0	0	0	0	0	0	0
⊢ -	1	2	0	0	1	3	0	0	0	0	2	3	0	0	1	0	1	2	1	780	0	0	0	2	0	1
<b>D</b> -	2	0	1	4	0	0	0	5	0	1	2	1	1	2	1	0	0	0	1	0	742	30	4	0	3	0
> -	0	0	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	5	0	2	27	750	1	1	10	0
≥ -	0	0	0	0	0	0	0	2	0	2	2	0	4	9	0	0	0	0	0	1	11	3	766	0	0	0
× -	3	0	0	2	0	2	0	2	0	0	16	2	1	2	0	0	1	1	0	2	1	4	1	744	15	1
> -	0	0	0	2	0	0	2	4	0	5	0	1	0	0	0	0	3	4	0	6	1	16	0	3	753	0
N -	1	1	1	1	6	0	2	1	2	3	1	1	0	0	0	0	2	1	0	2	0	0	0	4	0	771
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