Fashion MNIST data analysis

- **by Madhura Ashtekar**

In [ ]:

```
#loading the required libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from keras.models import Sequential
from keras.layers import Dense, Flatten
from keras.utils.np_utils import to_categorical
from keras.datasets import fashion_mnist
from keras.optimizers import Adam
from sklearn.model_selection import train_test_split
```

In [ ]:

```
#loading the dataset
(X, y), (X_test, y_test) = fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-l
abels-idx1-ubyte.gz
29515/29515 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-i
mages-idx3-ubyte.gz
26421880/26421880 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-la
bels-idx1-ubyte.gz
5148/5148 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-im
ages-idx3-ubyte.gz
4422102/4422102 [==============================] - 0s 0us/step
```

In [ ]:

```
#data preprocessing

accuracy_val={}

#normalising the data
X=X/255
X_test=X_test/255

#One hot encoding
y=to_categorical(y)
y_test=to_categorical(y_test)

#reshaping data
X=X.reshape((-1, 28, 28))
X_test=X_test.reshape((-1, 28, 28))

#splitting the training set into training set and validation
X_train, X_val, y_train, y_val=train_test_split(X, y, test_size=0.16)
```

In [ ]:

```
print(X_train.shape)
print(y_train.shape)

print(X_val.shape)
print(y_val.shape)

print(X_test.shape)
```

```
print(y_test.shape)
```

```
(50400, 28, 28)
(50400, 10)
(9600, 28, 28)
(9600, 10)
(10000, 28, 28)
(10000, 10)
```

Build a fully connected (dense) feedforward neural network with two hidden layers using Keras(within Tensorflow) and train it on 50k Fashion MNIST training images. First hidden layer should contain 200 neurons and second hidden layer should contain 50 neurons. The hidden layers should have ReLU activation function. Train the network for 100 epochs. Plot training and validation loss and accuracy as a function of training epochs. Try three different learning rates of your choice (make the plots for each learning rate).

In [ ]:

```
#Building the model with learning rate as 0.001

nn1_model=Sequential()
nn1_model.add(Flatten(input_shape=(28, 28)))
nn1_model.add(Dense(200,activation='relu'))
nn1_model.add(Dense(50,activation='relu'))
nn1_model.add(Dense(10,activation='softmax'))
nn1_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten (Flatten)           (None, 784)               0

 dense (Dense)               (None, 200)               157000

 dense_1 (Dense)             (None, 50)                10050

 dense_2 (Dense)             (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
#compiling the model using adam optimizer using learning rate 0.001
nn1_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.001), metrics=['a
ccuracy'])
lr1_model=nn1_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)
```

```
/usr/local/lib/python3.9/dist-packages/keras/optimizers/legacy/adam.py:117: UserWarning:
The `lr` argument is deprecated, use `learning_rate` instead.
  super().__init__(name, **kwargs)
```

```
Epoch 1/100
315/315 [==============================] - 3s 8ms/step - loss: 0.5807 - accuracy: 0.7975
- val_loss: 0.4446 - val_accuracy: 0.8434
Epoch 2/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4104 - accuracy: 0.8545
- val_loss: 0.4120 - val_accuracy: 0.8544
Epoch 3/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3613 - accuracy: 0.8708
- val_loss: 0.3719 - val_accuracy: 0.8680
Epoch 4/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3386 - accuracy: 0.8789
- val_loss: 0.3467 - val_accuracy: 0.8748
Epoch 5/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3171 - accuracy: 0.8844
```

- val_loss: 0.3500 - val_accuracy: 0.8713
Epoch 6/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2996 - accuracy: 0.8904
- val_loss: 0.3322 - val_accuracy: 0.8816
Epoch 7/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2862 - accuracy: 0.8945
- val_loss: 0.3668 - val_accuracy: 0.8691
Epoch 8/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2738 - accuracy: 0.9001
- val_loss: 0.3335 - val_accuracy: 0.8819
Epoch 9/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2629 - accuracy: 0.9019
- val_loss: 0.3206 - val_accuracy: 0.8852
Epoch 10/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2490 - accuracy: 0.9079
- val_loss: 0.3195 - val_accuracy: 0.8884
Epoch 11/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2434 - accuracy: 0.9099
- val_loss: 0.3202 - val_accuracy: 0.8848
Epoch 12/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2353 - accuracy: 0.9124
- val_loss: 0.3268 - val_accuracy: 0.8841
Epoch 13/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2276 - accuracy: 0.9150
- val_loss: 0.3193 - val_accuracy: 0.8892
Epoch 14/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2225 - accuracy: 0.9158
- val_loss: 0.3220 - val_accuracy: 0.8886
Epoch 15/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2099 - accuracy: 0.9218
- val_loss: 0.3149 - val_accuracy: 0.8907
Epoch 16/100
315/315 [==============================] - 2s 8ms/step - loss: 0.2030 - accuracy: 0.9234
- val_loss: 0.3327 - val_accuracy: 0.8855
Epoch 17/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2002 - accuracy: 0.9251
- val_loss: 0.3215 - val_accuracy: 0.8890
Epoch 18/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1931 - accuracy: 0.9276
- val_loss: 0.3350 - val_accuracy: 0.8889
Epoch 19/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1880 - accuracy: 0.9300
- val_loss: 0.3345 - val_accuracy: 0.8919
Epoch 20/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1799 - accuracy: 0.9314
- val_loss: 0.3298 - val_accuracy: 0.8936
Epoch 21/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1739 - accuracy: 0.9341
- val_loss: 0.3372 - val_accuracy: 0.8917
Epoch 22/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1674 - accuracy: 0.9371
- val_loss: 0.3363 - val_accuracy: 0.8913
Epoch 23/100
315/315 [==============================] - 2s 8ms/step - loss: 0.1673 - accuracy: 0.9370
- val_loss: 0.3480 - val_accuracy: 0.8874
Epoch 24/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1577 - accuracy: 0.9416
- val_loss: 0.3475 - val_accuracy: 0.8872
Epoch 25/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1560 - accuracy: 0.9420
- val_loss: 0.3299 - val_accuracy: 0.8940
Epoch 26/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1516 - accuracy: 0.9429
- val_loss: 0.3577 - val_accuracy: 0.8891
Epoch 27/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1502 - accuracy: 0.9450
- val_loss: 0.3490 - val_accuracy: 0.8925
Epoch 28/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1407 - accuracy: 0.9478
- val_loss: 0.3580 - val_accuracy: 0.8906
Epoch 29/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1373 - accuracy: 0.9480

```
- val_loss: 0.3771 - val_accuracy: 0.8906
Epoch 30/100
315/315 [==============================] - 3s 8ms/step - loss: 0.1333 - accuracy: 0.9501
- val_loss: 0.3626 - val_accuracy: 0.8883
Epoch 31/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1297 - accuracy: 0.9524
- val_loss: 0.3778 - val_accuracy: 0.8908
Epoch 32/100
315/315 [==============================] - 3s 8ms/step - loss: 0.1244 - accuracy: 0.9536
- val_loss: 0.3791 - val_accuracy: 0.8909
Epoch 33/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1216 - accuracy: 0.9549
- val_loss: 0.3764 - val_accuracy: 0.8927
Epoch 34/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1193 - accuracy: 0.9548
- val_loss: 0.4054 - val_accuracy: 0.8904
Epoch 35/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1135 - accuracy: 0.9568
- val_loss: 0.3918 - val_accuracy: 0.8916
Epoch 36/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1126 - accuracy: 0.9585
- val_loss: 0.3850 - val_accuracy: 0.8928
Epoch 37/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1131 - accuracy: 0.9584
- val_loss: 0.3922 - val_accuracy: 0.8941
Epoch 38/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1082 - accuracy: 0.9594
- val_loss: 0.4366 - val_accuracy: 0.8919
Epoch 39/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1021 - accuracy: 0.9614
- val_loss: 0.4342 - val_accuracy: 0.8871
Epoch 40/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0961 - accuracy: 0.9635
- val_loss: 0.4046 - val_accuracy: 0.8966
Epoch 41/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0991 - accuracy: 0.9626
- val_loss: 0.4294 - val_accuracy: 0.8916
Epoch 42/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0942 - accuracy: 0.9646
- val_loss: 0.4422 - val_accuracy: 0.8950
Epoch 43/100
315/315 [==============================] - 3s 9ms/step - loss: 0.0926 - accuracy: 0.9652
- val_loss: 0.4231 - val_accuracy: 0.8904
Epoch 44/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0937 - accuracy: 0.9655
- val_loss: 0.4516 - val_accuracy: 0.8842
Epoch 45/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0897 - accuracy: 0.9671
- val_loss: 0.4706 - val_accuracy: 0.8909
Epoch 46/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0861 - accuracy: 0.9678
- val_loss: 0.4614 - val_accuracy: 0.8927
Epoch 47/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0833 - accuracy: 0.9692
- val_loss: 0.4605 - val_accuracy: 0.8930
Epoch 48/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0853 - accuracy: 0.9676
- val_loss: 0.4535 - val_accuracy: 0.8943
Epoch 49/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0775 - accuracy: 0.9719
- val_loss: 0.4898 - val_accuracy: 0.8884
Epoch 50/100
315/315 [==============================] - 3s 8ms/step - loss: 0.0796 - accuracy: 0.9704
- val_loss: 0.4809 - val_accuracy: 0.8856
Epoch 51/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0792 - accuracy: 0.9701
- val_loss: 0.4854 - val_accuracy: 0.8829
Epoch 52/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0798 - accuracy: 0.9698
- val_loss: 0.4848 - val_accuracy: 0.8879
Epoch 53/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0738 - accuracy: 0.9724
```

- val_loss: 0.5124 - val_accuracy: 0.8896
Epoch 54/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0692 - accuracy: 0.9742
- val_loss: 0.5228 - val_accuracy: 0.8906
Epoch 55/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0669 - accuracy: 0.9753
- val_loss: 0.5236 - val_accuracy: 0.8883
Epoch 56/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0676 - accuracy: 0.9752
- val_loss: 0.5049 - val_accuracy: 0.8938
Epoch 57/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0653 - accuracy: 0.9761
- val_loss: 0.5325 - val_accuracy: 0.8921
Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0652 - accuracy: 0.9767
- val_loss: 0.5306 - val_accuracy: 0.8898
Epoch 59/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0657 - accuracy: 0.9753
- val_loss: 0.5274 - val_accuracy: 0.8898
Epoch 60/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0622 - accuracy: 0.9767
- val_loss: 0.5466 - val_accuracy: 0.8868
Epoch 61/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0587 - accuracy: 0.9775
- val_loss: 0.5507 - val_accuracy: 0.8889
Epoch 62/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0635 - accuracy: 0.9763
- val_loss: 0.5696 - val_accuracy: 0.8895
Epoch 63/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0590 - accuracy: 0.9779
- val_loss: 0.5704 - val_accuracy: 0.8906
Epoch 64/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0523 - accuracy: 0.9808
- val_loss: 0.5823 - val_accuracy: 0.8914
Epoch 65/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0633 - accuracy: 0.9764
- val_loss: 0.5759 - val_accuracy: 0.8827
Epoch 66/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0640 - accuracy: 0.9763
- val_loss: 0.5530 - val_accuracy: 0.8936
Epoch 67/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0508 - accuracy: 0.9812
- val_loss: 0.5519 - val_accuracy: 0.8922
Epoch 68/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0489 - accuracy: 0.9823
- val_loss: 0.6117 - val_accuracy: 0.8910
Epoch 69/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0528 - accuracy: 0.9810
- val_loss: 0.5634 - val_accuracy: 0.8922
Epoch 70/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0548 - accuracy: 0.9796
- val_loss: 0.5900 - val_accuracy: 0.8910
Epoch 71/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0478 - accuracy: 0.9828
- val_loss: 0.6547 - val_accuracy: 0.8845
Epoch 72/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0472 - accuracy: 0.9824
- val_loss: 0.5962 - val_accuracy: 0.8894
Epoch 73/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0509 - accuracy: 0.9802
- val_loss: 0.6067 - val_accuracy: 0.8841
Epoch 74/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0521 - accuracy: 0.9813
- val_loss: 0.6158 - val_accuracy: 0.8884
Epoch 75/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0513 - accuracy: 0.9806
- val_loss: 0.6364 - val_accuracy: 0.8869
Epoch 76/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0493 - accuracy: 0.9816
- val_loss: 0.6268 - val_accuracy: 0.8886
Epoch 77/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0465 - accuracy: 0.9821

```
- val_loss: 0.6355 - val_accuracy: 0.8877
Epoch 78/100
315/315 [==============================] - 2s 8ms/step - loss: 0.0561 - accuracy: 0.9794
- val_loss: 0.6207 - val_accuracy: 0.8877
Epoch 79/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0389 - accuracy: 0.9859
- val_loss: 0.6305 - val_accuracy: 0.8912
Epoch 80/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0411 - accuracy: 0.9845
- val_loss: 0.6539 - val_accuracy: 0.8922
Epoch 81/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0436 - accuracy: 0.9835
- val_loss: 0.6489 - val_accuracy: 0.8872
Epoch 82/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0412 - accuracy: 0.9847
- val_loss: 0.6540 - val_accuracy: 0.8843
Epoch 83/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0408 - accuracy: 0.9845
- val_loss: 0.6622 - val_accuracy: 0.8909
Epoch 84/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0371 - accuracy: 0.9866
- val_loss: 0.6660 - val_accuracy: 0.8926
Epoch 85/100
315/315 [==============================] - 3s 9ms/step - loss: 0.0353 - accuracy: 0.9873
- val_loss: 0.6904 - val_accuracy: 0.8912
Epoch 86/100
315/315 [==============================] - 2s 8ms/step - loss: 0.0526 - accuracy: 0.9817
- val_loss: 0.6862 - val_accuracy: 0.8883
Epoch 87/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0382 - accuracy: 0.9859
- val_loss: 0.6510 - val_accuracy: 0.8892
Epoch 88/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0304 - accuracy: 0.9891
- val_loss: 0.6802 - val_accuracy: 0.8898
Epoch 89/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0365 - accuracy: 0.9868
- val_loss: 0.6820 - val_accuracy: 0.8845
Epoch 90/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0408 - accuracy: 0.9854
- val_loss: 0.6998 - val_accuracy: 0.8920
Epoch 91/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0388 - accuracy: 0.9862
- val_loss: 0.6785 - val_accuracy: 0.8887
Epoch 92/100
315/315 [==============================] - 2s 8ms/step - loss: 0.0395 - accuracy: 0.9859
- val_loss: 0.6914 - val_accuracy: 0.8922
Epoch 93/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0289 - accuracy: 0.9894
- val_loss: 0.7266 - val_accuracy: 0.8908
Epoch 94/100
315/315 [==============================] - 2s 6ms/step - loss: 0.0385 - accuracy: 0.9861
- val_loss: 0.7049 - val_accuracy: 0.8920
Epoch 95/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0382 - accuracy: 0.9861
- val_loss: 0.7711 - val_accuracy: 0.8834
Epoch 96/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0361 - accuracy: 0.9870
- val_loss: 0.7222 - val_accuracy: 0.8878
Epoch 97/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0427 - accuracy: 0.9851
- val_loss: 0.7401 - val_accuracy: 0.8898
Epoch 98/100
315/315 [==============================] - 2s 5ms/step - loss: 0.0386 - accuracy: 0.9854
- val_loss: 0.7531 - val_accuracy: 0.8902
Epoch 99/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0466 - accuracy: 0.9826
- val_loss: 0.7370 - val_accuracy: 0.8888
Epoch 100/100
315/315 [==============================] - 2s 7ms/step - loss: 0.0217 - accuracy: 0.9925
- val_loss: 0.7300 - val_accuracy: 0.8942
```

In [ ]:

```
#accuracy using validation set
val_loss, val_acc1=nn1_model.evaluate(X_val, y_val)
accuracy_val[val_acc1]=0.001
print("Accuracy with learning rate=0.001 is ", val_acc1)
```

```
300/300 [==============================] - 1s 2ms/step - loss: 0.7008 - accuracy: 0.8929
Accuracy with learning rate=0.001 is  0.8929166793823242
```

In [ ]:

```
#Building the model with learning rate as 0.01

nn2_model=Sequential()
nn2_model.add(Flatten(input_shape=(28, 28)))
nn2_model.add(Dense(200,activation='relu'))
nn2_model.add(Dense(50,activation='relu'))
nn2_model.add(Dense(10,activation='softmax'))
nn2_model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_1 (Flatten)         (None, 784)               0

 dense_3 (Dense)             (None, 200)               157000

 dense_4 (Dense)             (None, 50)                10050

 dense_5 (Dense)             (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
#compiling the model using adam optimizer using learning rate 0.001
nn2_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.01), metrics=['ac
curacy'])
lr2_model=nn2_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)
```

```
Epoch 1/100
315/315 [==============================] - 2s 6ms/step - loss: 0.5761 - accuracy: 0.7923
- val_loss: 0.4296 - val_accuracy: 0.8450
Epoch 2/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4106 - accuracy: 0.8505
- val_loss: 0.4134 - val_accuracy: 0.8436
Epoch 3/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3765 - accuracy: 0.8620
- val_loss: 0.3847 - val_accuracy: 0.8586
Epoch 4/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3610 - accuracy: 0.8684
- val_loss: 0.3994 - val_accuracy: 0.8563
Epoch 5/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3456 - accuracy: 0.8748
- val_loss: 0.3723 - val_accuracy: 0.8618
Epoch 6/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3293 - accuracy: 0.8783
- val_loss: 0.3629 - val_accuracy: 0.8713
Epoch 7/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3252 - accuracy: 0.8802
- val_loss: 0.3546 - val_accuracy: 0.8711
Epoch 8/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3119 - accuracy: 0.8852
- val_loss: 0.3709 - val_accuracy: 0.8675
Epoch 9/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3053 - accuracy: 0.8869
```

- val_loss: 0.3553 - val_accuracy: 0.8742
Epoch 10/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3059 - accuracy: 0.8871
- val_loss: 0.3438 - val_accuracy: 0.8799
Epoch 11/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2959 - accuracy: 0.8905
- val_loss: 0.4079 - val_accuracy: 0.8621
Epoch 12/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2938 - accuracy: 0.8918
- val_loss: 0.4285 - val_accuracy: 0.8539
Epoch 13/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2903 - accuracy: 0.8921
- val_loss: 0.3703 - val_accuracy: 0.8728
Epoch 14/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2882 - accuracy: 0.8930
- val_loss: 0.3552 - val_accuracy: 0.8809
Epoch 15/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2822 - accuracy: 0.8964
- val_loss: 0.3822 - val_accuracy: 0.8745
Epoch 16/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2778 - accuracy: 0.8969
- val_loss: 0.3877 - val_accuracy: 0.8703
Epoch 17/100
315/315 [==============================] - 2s 8ms/step - loss: 0.2653 - accuracy: 0.9022
- val_loss: 0.3650 - val_accuracy: 0.8806
Epoch 18/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2748 - accuracy: 0.8991
- val_loss: 0.4248 - val_accuracy: 0.8601
Epoch 19/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2604 - accuracy: 0.9026
- val_loss: 0.4034 - val_accuracy: 0.8753
Epoch 20/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2674 - accuracy: 0.9014
- val_loss: 0.3808 - val_accuracy: 0.8769
Epoch 21/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2602 - accuracy: 0.9042
- val_loss: 0.3915 - val_accuracy: 0.8786
Epoch 22/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2619 - accuracy: 0.9021
- val_loss: 0.3827 - val_accuracy: 0.8819
Epoch 23/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2539 - accuracy: 0.9057
- val_loss: 0.3930 - val_accuracy: 0.8683
Epoch 24/100
315/315 [==============================] - 2s 8ms/step - loss: 0.2511 - accuracy: 0.9072
- val_loss: 0.3836 - val_accuracy: 0.8756
Epoch 25/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2532 - accuracy: 0.9062
- val_loss: 0.3811 - val_accuracy: 0.8778
Epoch 26/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2450 - accuracy: 0.9076
- val_loss: 0.3903 - val_accuracy: 0.8821
Epoch 27/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2399 - accuracy: 0.9100
- val_loss: 0.4030 - val_accuracy: 0.8776
Epoch 28/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2435 - accuracy: 0.9101
- val_loss: 0.3742 - val_accuracy: 0.8788
Epoch 29/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2429 - accuracy: 0.9101
- val_loss: 0.3875 - val_accuracy: 0.8847
Epoch 30/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2393 - accuracy: 0.9108
- val_loss: 0.4037 - val_accuracy: 0.8785
Epoch 31/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2332 - accuracy: 0.9126
- val_loss: 0.4133 - val_accuracy: 0.8778
Epoch 32/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2334 - accuracy: 0.9151
- val_loss: 0.4213 - val_accuracy: 0.8723
Epoch 33/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2344 - accuracy: 0.9142

- val_loss: 0.4244 - val_accuracy: 0.8796
Epoch 34/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2269 - accuracy: 0.9174
- val_loss: 0.4213 - val_accuracy: 0.8781
Epoch 35/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2361 - accuracy: 0.9119
- val_loss: 0.4107 - val_accuracy: 0.8806
Epoch 36/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2248 - accuracy: 0.9153
- val_loss: 0.4515 - val_accuracy: 0.8782
Epoch 37/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2158 - accuracy: 0.9206
- val_loss: 0.4399 - val_accuracy: 0.8752
Epoch 38/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2270 - accuracy: 0.9172
- val_loss: 0.4559 - val_accuracy: 0.8735
Epoch 39/100
315/315 [==============================] - 2s 7ms/step - loss: 0.2271 - accuracy: 0.9171
- val_loss: 0.4184 - val_accuracy: 0.8810
Epoch 40/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2336 - accuracy: 0.9159
- val_loss: 0.5166 - val_accuracy: 0.8673
Epoch 41/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2181 - accuracy: 0.9190
- val_loss: 0.4380 - val_accuracy: 0.8779
Epoch 42/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2178 - accuracy: 0.9195
- val_loss: 0.4475 - val_accuracy: 0.8808
Epoch 43/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2157 - accuracy: 0.9209
- val_loss: 0.4344 - val_accuracy: 0.8725
Epoch 44/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2108 - accuracy: 0.9227
- val_loss: 0.4430 - val_accuracy: 0.8783
Epoch 45/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2142 - accuracy: 0.9215
- val_loss: 0.4972 - val_accuracy: 0.8726
Epoch 46/100
315/315 [==============================] - 2s 8ms/step - loss: 0.2152 - accuracy: 0.9223
- val_loss: 0.4507 - val_accuracy: 0.8809
Epoch 47/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2221 - accuracy: 0.9187
- val_loss: 0.4662 - val_accuracy: 0.8735
Epoch 48/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2124 - accuracy: 0.9220
- val_loss: 0.4876 - val_accuracy: 0.8770
Epoch 49/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2058 - accuracy: 0.9250
- val_loss: 0.4300 - val_accuracy: 0.8782
Epoch 50/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2040 - accuracy: 0.9262
- val_loss: 0.5036 - val_accuracy: 0.8759
Epoch 51/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2001 - accuracy: 0.9267
- val_loss: 0.4643 - val_accuracy: 0.8801
Epoch 52/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2005 - accuracy: 0.9268
- val_loss: 0.4545 - val_accuracy: 0.8783
Epoch 53/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1962 - accuracy: 0.9269
- val_loss: 0.4618 - val_accuracy: 0.8809
Epoch 54/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2082 - accuracy: 0.9249
- val_loss: 0.4828 - val_accuracy: 0.8818
Epoch 55/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2018 - accuracy: 0.9262
- val_loss: 0.4770 - val_accuracy: 0.8826
Epoch 56/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1926 - accuracy: 0.9294
- val_loss: 0.5085 - val_accuracy: 0.8788
Epoch 57/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1993 - accuracy: 0.9279

- val_loss: 0.4873 - val_accuracy: 0.8781
Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1949 - accuracy: 0.9287
- val_loss: 0.4984 - val_accuracy: 0.8765
Epoch 59/100
315/315 [==============================] - 2s 6ms/step - loss: 0.2001 - accuracy: 0.9271
- val_loss: 0.5218 - val_accuracy: 0.8750
Epoch 60/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1968 - accuracy: 0.9287
- val_loss: 0.4745 - val_accuracy: 0.8788
Epoch 61/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1843 - accuracy: 0.9312
- val_loss: 0.5153 - val_accuracy: 0.8788
Epoch 62/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1932 - accuracy: 0.9305
- val_loss: 0.5437 - val_accuracy: 0.8688
Epoch 63/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1993 - accuracy: 0.9275
- val_loss: 0.5777 - val_accuracy: 0.8758
Epoch 64/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2096 - accuracy: 0.9265
- val_loss: 0.5368 - val_accuracy: 0.8742
Epoch 65/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1935 - accuracy: 0.9315
- val_loss: 0.5524 - val_accuracy: 0.8769
Epoch 66/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1815 - accuracy: 0.9337
- val_loss: 0.5336 - val_accuracy: 0.8719
Epoch 67/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1833 - accuracy: 0.9334
- val_loss: 0.5370 - val_accuracy: 0.8801
Epoch 68/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1915 - accuracy: 0.9312
- val_loss: 0.5415 - val_accuracy: 0.8772
Epoch 69/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2055 - accuracy: 0.9283
- val_loss: 0.5542 - val_accuracy: 0.8726
Epoch 70/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1808 - accuracy: 0.9349
- val_loss: 0.5447 - val_accuracy: 0.8769
Epoch 71/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1797 - accuracy: 0.9347
- val_loss: 0.5681 - val_accuracy: 0.8712
Epoch 72/100
315/315 [==============================] - 2s 5ms/step - loss: 0.2004 - accuracy: 0.9275
- val_loss: 0.5900 - val_accuracy: 0.8701
Epoch 73/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1700 - accuracy: 0.9378
- val_loss: 0.5875 - val_accuracy: 0.8730
Epoch 74/100
315/315 [==============================] - 2s 7ms/step - loss: 0.1855 - accuracy: 0.9346
- val_loss: 0.5226 - val_accuracy: 0.8756
Epoch 75/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1750 - accuracy: 0.9358
- val_loss: 0.5853 - val_accuracy: 0.8718
Epoch 76/100
315/315 [==============================] - 3s 8ms/step - loss: 0.1736 - accuracy: 0.9372
- val_loss: 0.5754 - val_accuracy: 0.8780
Epoch 77/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1780 - accuracy: 0.9349
- val_loss: 0.5576 - val_accuracy: 0.8783
Epoch 78/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1639 - accuracy: 0.9394
- val_loss: 0.5541 - val_accuracy: 0.8786
Epoch 79/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1787 - accuracy: 0.9361
- val_loss: 0.5337 - val_accuracy: 0.8789
Epoch 80/100
315/315 [==============================] - 3s 8ms/step - loss: 0.1840 - accuracy: 0.9347
- val_loss: 0.5970 - val_accuracy: 0.8768
Epoch 81/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1732 - accuracy: 0.9372

```
- val_loss: 0.5506 - val_accuracy: 0.8745
Epoch 82/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1749 - accuracy: 0.9364
- val_loss: 0.6064 - val_accuracy: 0.8782
Epoch 83/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1789 - accuracy: 0.9362
- val_loss: 0.6045 - val_accuracy: 0.8719
Epoch 84/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1815 - accuracy: 0.9344
- val_loss: 0.5434 - val_accuracy: 0.8782
Epoch 85/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1692 - accuracy: 0.9392
- val_loss: 0.6191 - val_accuracy: 0.8791
Epoch 86/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1833 - accuracy: 0.9376
- val_loss: 0.6044 - val_accuracy: 0.8765
Epoch 87/100
315/315 [==============================] - 2s 8ms/step - loss: 0.1749 - accuracy: 0.9384
- val_loss: 0.5812 - val_accuracy: 0.8791
Epoch 88/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1668 - accuracy: 0.9405
- val_loss: 0.6778 - val_accuracy: 0.8807
Epoch 89/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1586 - accuracy: 0.9420
- val_loss: 0.6207 - val_accuracy: 0.8769
Epoch 90/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1627 - accuracy: 0.9415
- val_loss: 0.6063 - val_accuracy: 0.8790
Epoch 91/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1571 - accuracy: 0.9422
- val_loss: 0.6153 - val_accuracy: 0.8779
Epoch 92/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1641 - accuracy: 0.9406
- val_loss: 0.6461 - val_accuracy: 0.8774
Epoch 93/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1840 - accuracy: 0.9351
- val_loss: 0.5943 - val_accuracy: 0.8832
Epoch 94/100
315/315 [==============================] - 3s 8ms/step - loss: 0.1617 - accuracy: 0.9421
- val_loss: 0.6016 - val_accuracy: 0.8802
Epoch 95/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1557 - accuracy: 0.9437
- val_loss: 0.6142 - val_accuracy: 0.8781
Epoch 96/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1890 - accuracy: 0.9345
- val_loss: 0.5441 - val_accuracy: 0.8726
Epoch 97/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1752 - accuracy: 0.9376
- val_loss: 0.5493 - val_accuracy: 0.8767
Epoch 98/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1606 - accuracy: 0.9410
- val_loss: 0.6189 - val_accuracy: 0.8795
Epoch 99/100
315/315 [==============================] - 2s 6ms/step - loss: 0.1569 - accuracy: 0.9430
- val_loss: 0.6411 - val_accuracy: 0.8784
Epoch 100/100
315/315 [==============================] - 2s 5ms/step - loss: 0.1575 - accuracy: 0.9427
- val_loss: 0.6615 - val_accuracy: 0.8805
```

In [ ]:

```
#accuracy using validation set
val_loss, val_acc2=nn2_model.evaluate(X_val, y_val)
accuracy_val[val_acc2]=0.01

print("Accuracy with learning rate=0.01 is ", val_acc2)
```

```
300/300 [==============================] - 1s 2ms/step - loss: 0.5588 - accuracy: 0.8821
Accuracy with learning rate=0.01 is  0.8820833563804626
```

In [ ]:

```
#Building the model with learning rate as 0.1

nn3_model=Sequential()
nn3_model.add(Flatten(input_shape=(28, 28)))
nn3_model.add(Dense(200,activation='relu'))
nn3_model.add(Dense(50,activation='relu'))
nn3_model.add(Dense(10,activation='softmax'))
nn3_model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_2 (Flatten)         (None, 784)               0

 dense_6 (Dense)             (None, 200)               157000

 dense_7 (Dense)             (None, 50)                10050

 dense_8 (Dense)             (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
#compiling the model using adam optimizer using learning rate 0.001
nn3_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.1), metrics=['acc
uracy'])
lr3_model=nn3_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)
```

```
/usr/local/lib/python3.9/dist-packages/keras/optimizers/legacy/adam.py:117: UserWarning:
The `lr` argument is deprecated, use `learning_rate` instead.
  super().__init__(name, **kwargs)
```

```
Epoch 1/100
315/315 [==============================] - 2s 6ms/step - loss: 64.6946 - accuracy: 0.7112
- val_loss: 1.0374 - val_accuracy: 0.7907
Epoch 2/100
315/315 [==============================] - 2s 5ms/step - loss: 0.8166 - accuracy: 0.7991
- val_loss: 0.6033 - val_accuracy: 0.8268
Epoch 3/100
315/315 [==============================] - 2s 7ms/step - loss: 0.5534 - accuracy: 0.8254
- val_loss: 0.5476 - val_accuracy: 0.8315
Epoch 4/100
315/315 [==============================] - 2s 7ms/step - loss: 0.5485 - accuracy: 0.8240
- val_loss: 0.5233 - val_accuracy: 0.8360
Epoch 5/100
315/315 [==============================] - 2s 5ms/step - loss: 0.5235 - accuracy: 0.8271
- val_loss: 0.4974 - val_accuracy: 0.8411
Epoch 6/100
315/315 [==============================] - 2s 5ms/step - loss: 3385.8572 - accuracy: 0.75
84 - val_loss: 31021.6250 - val_accuracy: 0.4782
Epoch 7/100
315/315 [==============================] - 2s 5ms/step - loss: 1524.8997 - accuracy: 0.74
93 - val_loss: 99.1333 - val_accuracy: 0.7858
Epoch 8/100
315/315 [==============================] - 2s 5ms/step - loss: 99.8309 - accuracy: 0.7720
- val_loss: 91.2949 - val_accuracy: 0.7875
Epoch 9/100
315/315 [==============================] - 2s 5ms/step - loss: 54.4224 - accuracy: 0.7846
- val_loss: 44.4808 - val_accuracy: 0.7702
Epoch 10/100
315/315 [==============================] - 2s 6ms/step - loss: 34.6604 - accuracy: 0.7916
- val_loss: 30.2579 - val_accuracy: 0.8039
Epoch 11/100
315/315 [==============================] - 2s 8ms/step - loss: 32.1851 - accuracy: 0.7872
- val_loss: 31.0187 - val_accuracy: 0.7858
```

```
Epoch 12/100
315/315 [==============================] - 2s 5ms/step - loss: 22.8857 - accuracy: 0.7927
- val_loss: 21.5294 - val_accuracy: 0.8005
Epoch 13/100
315/315 [==============================] - 2s 5ms/step - loss: 21.5944 - accuracy: 0.7885
- val_loss: 23.8072 - val_accuracy: 0.7932
Epoch 14/100
315/315 [==============================] - 2s 5ms/step - loss: 16.6287 - accuracy: 0.7923
- val_loss: 16.1800 - val_accuracy: 0.7837
Epoch 15/100
315/315 [==============================] - 2s 5ms/step - loss: 11.2299 - accuracy: 0.7945
- val_loss: 15.4102 - val_accuracy: 0.7692
Epoch 16/100
315/315 [==============================] - 2s 5ms/step - loss: 12.6874 - accuracy: 0.7884
- val_loss: 9.1948 - val_accuracy: 0.8062
Epoch 17/100
315/315 [==============================] - 2s 5ms/step - loss: 13.4703 - accuracy: 0.7826
- val_loss: 11.9568 - val_accuracy: 0.7705
Epoch 18/100
315/315 [==============================] - 3s 8ms/step - loss: 16.3392 - accuracy: 0.7808
- val_loss: 8.6360 - val_accuracy: 0.7660
Epoch 19/100
315/315 [==============================] - 2s 5ms/step - loss: 9.4679 - accuracy: 0.7862
- val_loss: 17.1896 - val_accuracy: 0.7242
Epoch 20/100
315/315 [==============================] - 2s 5ms/step - loss: 7.4098 - accuracy: 0.7877
- val_loss: 9.3380 - val_accuracy: 0.7444
Epoch 21/100
315/315 [==============================] - 2s 5ms/step - loss: 11.3118 - accuracy: 0.7722
- val_loss: 77.2837 - val_accuracy: 0.7175
Epoch 22/100
315/315 [==============================] - 2s 5ms/step - loss: 6422.1904 - accuracy: 0.71
45 - val_loss: 249.5360 - val_accuracy: 0.7694
Epoch 23/100
315/315 [==============================] - 2s 5ms/step - loss: 150.6926 - accuracy: 0.789
7 - val_loss: 101.1658 - val_accuracy: 0.8122
Epoch 24/100
315/315 [==============================] - 2s 5ms/step - loss: 77.4669 - accuracy: 0.7977
- val_loss: 74.6787 - val_accuracy: 0.7999
Epoch 25/100
315/315 [==============================] - 2s 7ms/step - loss: 56.3856 - accuracy: 0.7945
- val_loss: 63.0074 - val_accuracy: 0.7828
Epoch 26/100
315/315 [==============================] - 2s 7ms/step - loss: 48.5597 - accuracy: 0.7944
- val_loss: 49.8718 - val_accuracy: 0.7972
Epoch 27/100
315/315 [==============================] - 2s 5ms/step - loss: 37.3484 - accuracy: 0.7961
- val_loss: 48.4536 - val_accuracy: 0.7309
Epoch 28/100
315/315 [==============================] - 2s 5ms/step - loss: 32.5677 - accuracy: 0.7958
- val_loss: 33.7216 - val_accuracy: 0.8128
Epoch 29/100
315/315 [==============================] - 2s 6ms/step - loss: 22.6371 - accuracy: 0.7994
- val_loss: 23.0975 - val_accuracy: 0.7938
Epoch 30/100
315/315 [==============================] - 2s 5ms/step - loss: 19.8276 - accuracy: 0.7972
- val_loss: 28.2508 - val_accuracy: 0.7616
Epoch 31/100
315/315 [==============================] - 2s 5ms/step - loss: 15.3896 - accuracy: 0.8008
- val_loss: 18.7770 - val_accuracy: 0.8001
Epoch 32/100
315/315 [==============================] - 2s 7ms/step - loss: 14.0826 - accuracy: 0.7979
- val_loss: 14.4927 - val_accuracy: 0.7798
Epoch 33/100
315/315 [==============================] - 2s 6ms/step - loss: 13.2806 - accuracy: 0.7955
- val_loss: 15.6472 - val_accuracy: 0.8022
Epoch 34/100
315/315 [==============================] - 2s 5ms/step - loss: 107.2731 - accuracy: 0.762
2 - val_loss: 93.8330 - val_accuracy: 0.7801
Epoch 35/100
315/315 [==============================] - 2s 5ms/step - loss: 19.6530 - accuracy: 0.7942
- val_loss: 12.3481 - val_accuracy: 0.7738
```

```
Epoch 36/100
315/315 [==============================] - 2s 5ms/step - loss: 7.3918 - accuracy: 0.7951
- val_loss: 11.9808 - val_accuracy: 0.8017
Epoch 37/100
315/315 [==============================] - 2s 5ms/step - loss: 6.4170 - accuracy: 0.7950
- val_loss: 8.4556 - val_accuracy: 0.7659
Epoch 38/100
315/315 [==============================] - 2s 6ms/step - loss: 4.8623 - accuracy: 0.7936
- val_loss: 9.0118 - val_accuracy: 0.7461
Epoch 39/100
315/315 [==============================] - 2s 7ms/step - loss: 6.5594 - accuracy: 0.7866
- val_loss: 10.8758 - val_accuracy: 0.7921
Epoch 40/100
315/315 [==============================] - 2s 7ms/step - loss: 7.8453 - accuracy: 0.7829
- val_loss: 32.0416 - val_accuracy: 0.6300
Epoch 41/100
315/315 [==============================] - 2s 5ms/step - loss: 6534.0234 - accuracy: 0.70
49 - val_loss: 366.7116 - val_accuracy: 0.7664
Epoch 42/100
315/315 [==============================] - 2s 5ms/step - loss: 224.4717 - accuracy: 0.792
0 - val_loss: 155.9272 - val_accuracy: 0.8000
Epoch 43/100
315/315 [==============================] - 2s 5ms/step - loss: 131.2662 - accuracy: 0.791
5 - val_loss: 106.1682 - val_accuracy: 0.8029
Epoch 44/100
315/315 [==============================] - 2s 5ms/step - loss: 82.4365 - accuracy: 0.8022
- val_loss: 89.4845 - val_accuracy: 0.8069
Epoch 45/100
315/315 [==============================] - 2s 5ms/step - loss: 58.8793 - accuracy: 0.7997
- val_loss: 64.8852 - val_accuracy: 0.7502
Epoch 46/100
315/315 [==============================] - 2s 7ms/step - loss: 54.6857 - accuracy: 0.8025
- val_loss: 47.6776 - val_accuracy: 0.8179
Epoch 47/100
315/315 [==============================] - 2s 7ms/step - loss: 32.5137 - accuracy: 0.8029
- val_loss: 45.1403 - val_accuracy: 0.8058
Epoch 48/100
315/315 [==============================] - 2s 5ms/step - loss: 27.7561 - accuracy: 0.8036
- val_loss: 29.9572 - val_accuracy: 0.8227
Epoch 49/100
315/315 [==============================] - 2s 5ms/step - loss: 23.2324 - accuracy: 0.8017
- val_loss: 31.8406 - val_accuracy: 0.7828
Epoch 50/100
315/315 [==============================] - 2s 5ms/step - loss: 23.2019 - accuracy: 0.8008
- val_loss: 21.7222 - val_accuracy: 0.8143
Epoch 51/100
315/315 [==============================] - 2s 5ms/step - loss: 15.4429 - accuracy: 0.7991
- val_loss: 24.6308 - val_accuracy: 0.7656
Epoch 52/100
315/315 [==============================] - 2s 5ms/step - loss: 13.8697 - accuracy: 0.7990
- val_loss: 25.1459 - val_accuracy: 0.7713
Epoch 53/100
315/315 [==============================] - 2s 6ms/step - loss: 18.7480 - accuracy: 0.7894
- val_loss: 21.5240 - val_accuracy: 0.8084
Epoch 54/100
315/315 [==============================] - 3s 8ms/step - loss: 15.7166 - accuracy: 0.7927
- val_loss: 21.3899 - val_accuracy: 0.7835
Epoch 55/100
315/315 [==============================] - 2s 5ms/step - loss: 17.1915 - accuracy: 0.7932
- val_loss: 16.4338 - val_accuracy: 0.7882
Epoch 56/100
315/315 [==============================] - 2s 5ms/step - loss: 180.7159 - accuracy: 0.755
8 - val_loss: 84.0303 - val_accuracy: 0.7511
Epoch 57/100
315/315 [==============================] - 2s 5ms/step - loss: 23.3943 - accuracy: 0.7896
- val_loss: 16.0453 - val_accuracy: 0.7891
Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 9.5252 - accuracy: 0.7940
- val_loss: 11.6870 - val_accuracy: 0.8023
Epoch 59/100
315/315 [==============================] - 2s 5ms/step - loss: 8.0996 - accuracy: 0.7921
- val loss: 10.7468 - val accuracy: 0.7853
```

```
Epoch 60/100
315/315 [==============================] - 2s 5ms/step - loss: 7.0828 - accuracy: 0.7891
- val_loss: 12.5214 - val_accuracy: 0.8081
Epoch 61/100
315/315 [==============================] - 2s 8ms/step - loss: 11.4248 - accuracy: 0.7826
- val_loss: 13.3889 - val_accuracy: 0.7945
Epoch 62/100
315/315 [==============================] - 2s 6ms/step - loss: 9.0303 - accuracy: 0.7835
- val_loss: 11.6248 - val_accuracy: 0.7605
Epoch 63/100
315/315 [==============================] - 2s 5ms/step - loss: 6.5934 - accuracy: 0.7829
- val_loss: 18.1603 - val_accuracy: 0.7806
Epoch 64/100
315/315 [==============================] - 2s 5ms/step - loss: 7791.8784 - accuracy: 0.72
46 - val_loss: 884.8655 - val_accuracy: 0.7838
Epoch 65/100
315/315 [==============================] - 2s 5ms/step - loss: 358.7847 - accuracy: 0.796
7 - val_loss: 203.7273 - val_accuracy: 0.8247
Epoch 66/100
315/315 [==============================] - 2s 5ms/step - loss: 174.5097 - accuracy: 0.800
3 - val_loss: 202.9422 - val_accuracy: 0.7809
Epoch 67/100
315/315 [==============================] - 2s 5ms/step - loss: 135.2509 - accuracy: 0.800
6 - val_loss: 127.2169 - val_accuracy: 0.8075
Epoch 68/100
315/315 [==============================] - 2s 7ms/step - loss: 98.6410 - accuracy: 0.8033
- val_loss: 120.0429 - val_accuracy: 0.7869
Epoch 69/100
315/315 [==============================] - 2s 7ms/step - loss: 87.2442 - accuracy: 0.8009
- val_loss: 77.3625 - val_accuracy: 0.8099
Epoch 70/100
315/315 [==============================] - 2s 5ms/step - loss: 62.7525 - accuracy: 0.8061
- val_loss: 67.1537 - val_accuracy: 0.7903
Epoch 71/100
315/315 [==============================] - 2s 5ms/step - loss: 50.1274 - accuracy: 0.8084
- val_loss: 57.9825 - val_accuracy: 0.7973
Epoch 72/100
315/315 [==============================] - 2s 5ms/step - loss: 42.2277 - accuracy: 0.8068
- val_loss: 46.0160 - val_accuracy: 0.7738
Epoch 73/100
315/315 [==============================] - 2s 5ms/step - loss: 33.4257 - accuracy: 0.8065
- val_loss: 53.3336 - val_accuracy: 0.7506
Epoch 74/100
315/315 [==============================] - 2s 5ms/step - loss: 35.5197 - accuracy: 0.8016
- val_loss: 39.2494 - val_accuracy: 0.8023
Epoch 75/100
315/315 [==============================] - 2s 7ms/step - loss: 34.3227 - accuracy: 0.8008
- val_loss: 38.8799 - val_accuracy: 0.7548
Epoch 76/100
315/315 [==============================] - 2s 7ms/step - loss: 24.5471 - accuracy: 0.8035
- val_loss: 26.1215 - val_accuracy: 0.7913
Epoch 77/100
315/315 [==============================] - 2s 5ms/step - loss: 4046.1084 - accuracy: 0.73
56 - val_loss: 246.3271 - val_accuracy: 0.8064
Epoch 78/100
315/315 [==============================] - 2s 5ms/step - loss: 127.2621 - accuracy: 0.804
1 - val_loss: 114.8820 - val_accuracy: 0.8331
Epoch 79/100
315/315 [==============================] - 2s 5ms/step - loss: 82.5135 - accuracy: 0.8064
- val_loss: 116.2027 - val_accuracy: 0.7929
Epoch 80/100
315/315 [==============================] - 2s 5ms/step - loss: 60.9815 - accuracy: 0.8055
- val_loss: 62.3407 - val_accuracy: 0.7953
Epoch 81/100
315/315 [==============================] - 2s 5ms/step - loss: 41.5837 - accuracy: 0.8069
- val_loss: 57.3734 - val_accuracy: 0.8050
Epoch 82/100
315/315 [==============================] - 2s 6ms/step - loss: 33.5540 - accuracy: 0.8084
- val_loss: 43.8134 - val_accuracy: 0.8087
Epoch 83/100
315/315 [==============================] - 2s 8ms/step - loss: 29.6041 - accuracy: 0.8064
- val loss: 41.1158 - val accuracy: 0.8045
```

```
Epoch 84/100
315/315 [==============================] - 2s 5ms/step - loss: 25.3827 - accuracy: 0.8063
- val_loss: 42.3204 - val_accuracy: 0.7829
Epoch 85/100
315/315 [==============================] - 2s 5ms/step - loss: 24.3657 - accuracy: 0.8025
- val_loss: 34.6197 - val_accuracy: 0.7835
Epoch 86/100
315/315 [==============================] - 2s 5ms/step - loss: 18.8163 - accuracy: 0.8010
- val_loss: 30.7793 - val_accuracy: 0.8050
Epoch 87/100
315/315 [==============================] - 2s 5ms/step - loss: 16.2922 - accuracy: 0.8042
- val_loss: 33.1493 - val_accuracy: 0.8000
Epoch 88/100
315/315 [==============================] - 2s 5ms/step - loss: 23.5247 - accuracy: 0.7973
- val_loss: 22.8305 - val_accuracy: 0.8095
Epoch 89/100
315/315 [==============================] - 2s 5ms/step - loss: 17.4991 - accuracy: 0.7961
- val_loss: 42.5346 - val_accuracy: 0.7808
Epoch 90/100
315/315 [==============================] - 3s 8ms/step - loss: 15.5114 - accuracy: 0.7947
- val_loss: 25.8032 - val_accuracy: 0.7638
Epoch 91/100
315/315 [==============================] - 2s 6ms/step - loss: 15.6447 - accuracy: 0.7920
- val_loss: 23.3395 - val_accuracy: 0.7869
Epoch 92/100
315/315 [==============================] - 2s 5ms/step - loss: 11.7278 - accuracy: 0.7928
- val_loss: 19.2250 - val_accuracy: 0.7739
Epoch 93/100
315/315 [==============================] - 2s 6ms/step - loss: 40.1081 - accuracy: 0.7744
- val_loss: 16.5754 - val_accuracy: 0.7520
Epoch 94/100
315/315 [==============================] - 2s 5ms/step - loss: 9.8073 - accuracy: 0.7909
- val_loss: 14.7309 - val_accuracy: 0.7521
Epoch 95/100
315/315 [==============================] - 2s 5ms/step - loss: 12.0335 - accuracy: 0.7854
- val_loss: 12.2495 - val_accuracy: 0.7954
Epoch 96/100
315/315 [==============================] - 2s 5ms/step - loss: 6.6353 - accuracy: 0.7914
- val_loss: 14.9415 - val_accuracy: 0.7766
Epoch 97/100
315/315 [==============================] - 2s 8ms/step - loss: 8.2156 - accuracy: 0.7814
- val_loss: 10.4919 - val_accuracy: 0.7817
Epoch 98/100
315/315 [==============================] - 2s 6ms/step - loss: 13.1750 - accuracy: 0.7658
- val_loss: 26.7483 - val_accuracy: 0.7510
Epoch 99/100
315/315 [==============================] - 2s 6ms/step - loss: 6718.3501 - accuracy: 0.73
28 - val_loss: 371.7867 - val_accuracy: 0.8139
Epoch 100/100
315/315 [==============================] - 2s 5ms/step - loss: 209.7486 - accuracy: 0.806
3 - val_loss: 167.1063 - val_accuracy: 0.8050
```

In [ ]:

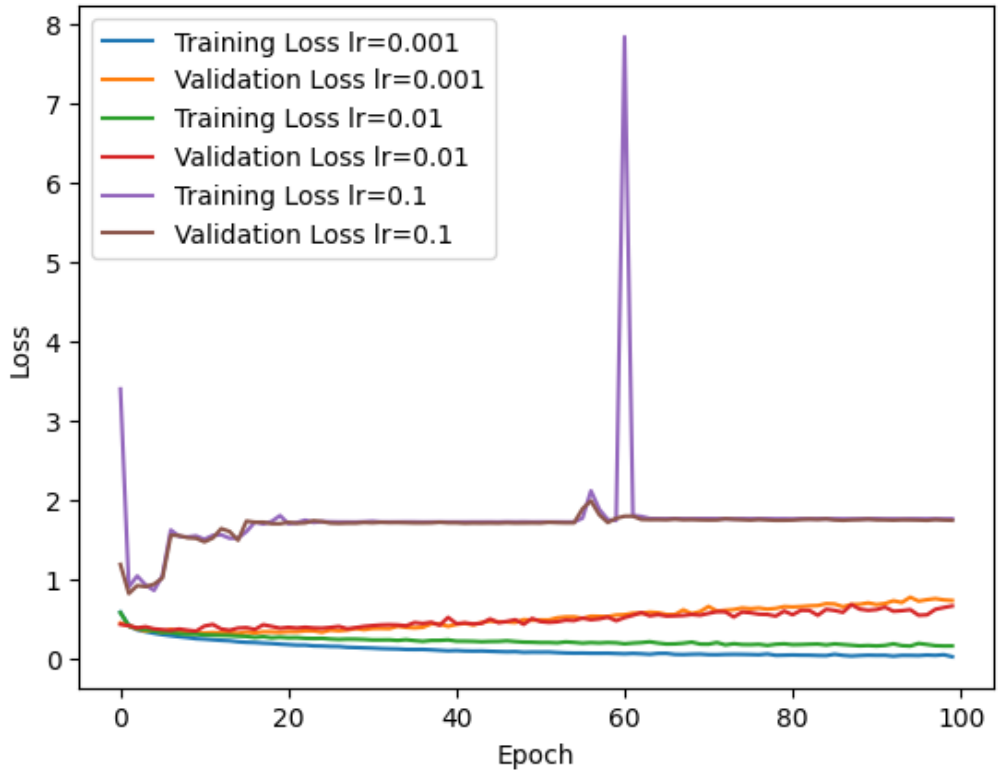
```
#accuracy using validation set
val_loss, val_acc3=nn3_model.evaluate(X_val, y_val)
accuracy_val[val_acc3]=0.1
print("Accuracy with learning rate=0.1 is ", val_acc3)
```

```
300/300 [==============================] - 1s 3ms/step - loss: 159.2406 - accuracy: 0.807
2
Accuracy with learning rate=0.1 is  0.8071874976158142
```

In [ ]:

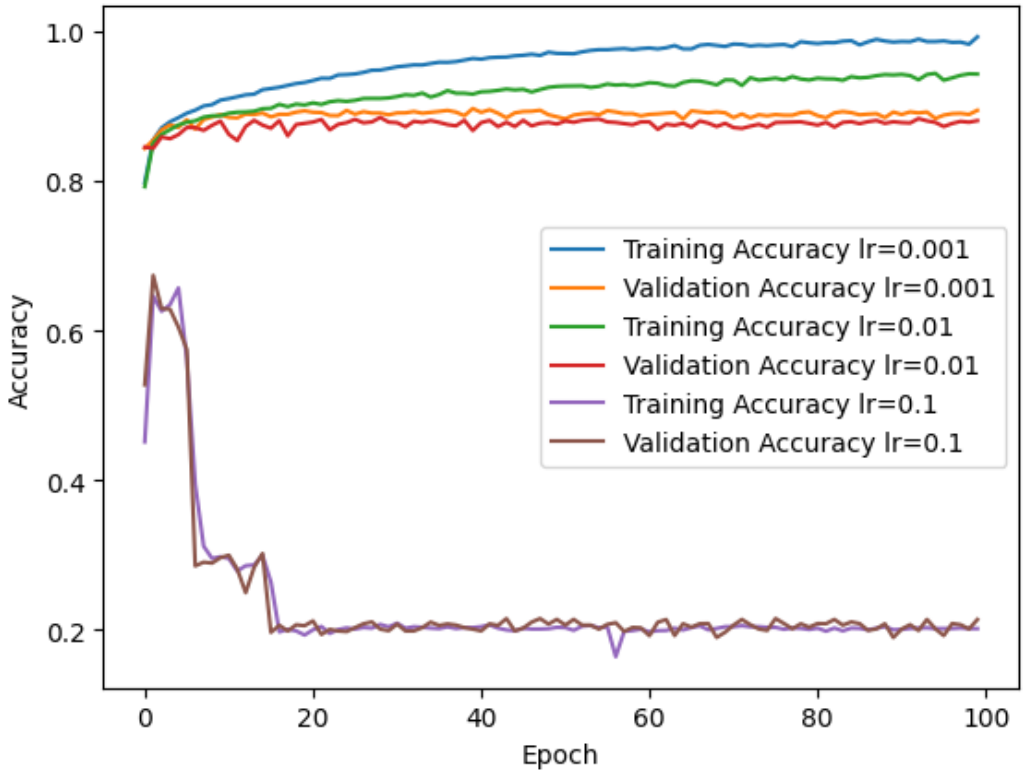
```
plt.plot(lr1_model.history['loss'], label='Training Loss lr=0.001')
plt.plot(lr1_model.history['val_loss'], label='Validation Loss lr=0.001')
plt.plot(lr2_model.history['loss'], label='Training Loss lr=0.01')
plt.plot(lr2_model.history['val_loss'], label='Validation Loss lr=0.01')
plt.plot(lr3_model.history['loss'], label='Training Loss lr=0.1')
plt.plot(lr3_model.history['val_loss'], label='Validation Loss lr=0.1')
```

```
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



In [ ]:

```
plt.plot(lr1_model.history['accuracy'], label='Training Accuracy lr=0.001')
plt.plot(lr1_model.history['val_accuracy'], label='Validation Accuracy lr=0.001')
plt.plot(lr2_model.history['accuracy'], label='Training Accuracy lr=0.01')
plt.plot(lr2_model.history['val_accuracy'], label='Validation Accuracy lr=0.01')
plt.plot(lr3_model.history['accuracy'], label='Training Accuracy lr=0.1')
plt.plot(lr3_model.history['val_accuracy'], label='Validation Accuracy lr=0.1')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



Run the network on the test portion of the dataset using best-performing learning rate and report loss and accuracy.

In [ ]:

```
#Accuracy and loss using the testing set
max_lr=max(accuracy_val.keys())
if max_lr==val_acc1:
  loss, accuracy=nn1_model.evaluate(X_test, y_test)
elif max_lr==val_acc2:
  loss, accuracy=nn2_model.evaluate(X_test, y_test)
else:
  loss, accuracy=nn3_model.evaluate(X_test, y_test)

print("Learning rate: ", accuracy_val[max_lr])
print("Loss: ", loss)
print("Accuracy: ", accuracy)
```

```
313/313 [==============================] - 1s 2ms/step - loss: 0.7634 - accuracy: 0.8910
Learning rate:  0.001
Loss:  0.7634335160255432
Accuracy:  0.890999972820282
```

How many parameters does the network have? How many of those parameters are bias parameters?

In [ ]:

```
print('Number of parameters:', nn1_model.count_params())
print('Number of bias parameters:', nn1_model.count_params() - sum([layer.count_params()
for layer in nn1_model.layers if 'kernel' in layer.name]))
```

```
Number of parameters: 167560
Number of bias parameters: 167560
```

Repeat everything from the previous step but make the hidden layers have linear activation functions.

In [ ]:

```
#Building the model with learning rate as 0.001

nn1_model=Sequential()
nn1_model.add(Flatten(input_shape=(28, 28)))
nn1_model.add(Dense(200,activation='linear'))
nn1_model.add(Dense(50,activation='linear'))
nn1_model.add(Dense(10,activation='softmax'))
nn1_model.summary()

#compiling the model using adam optimizer using learning rate 0.001
nn1_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.001), metrics=['a
ccuracy'])
lr1_model=nn1_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)

#accuracy using validation set
val_loss, val_acc1=nn1_model.evaluate(X_val, y_val)
accuracy_val[val_acc1]=0.001
print("Accuracy with learning rate=0.001 is ", val_acc1)
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_3 (Flatten)         (None, 784)               0

 dense_9 (Dense)             (None, 200)               157000

 dense_10 (Dense)            (None, 50)                10050
```

```
 dense_10 (Dense)            (None, 50)                10050

 dense_11 (Dense)            (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
Epoch 1/100
315/315 [==============================] - 2s 6ms/step - loss: 0.5991 - accuracy: 0.7913
- val_loss: 0.5084 - val_accuracy: 0.8209
Epoch 2/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4690 - accuracy: 0.8368
- val_loss: 0.4586 - val_accuracy: 0.8438
Epoch 3/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4507 - accuracy: 0.8420
- val_loss: 0.4563 - val_accuracy: 0.8416
Epoch 4/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4382 - accuracy: 0.8477
- val_loss: 0.4379 - val_accuracy: 0.8514
Epoch 5/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4242 - accuracy: 0.8510
- val_loss: 0.4438 - val_accuracy: 0.8465
Epoch 6/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4206 - accuracy: 0.8538
- val_loss: 0.4491 - val_accuracy: 0.8420
Epoch 7/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4082 - accuracy: 0.8578
- val_loss: 0.4456 - val_accuracy: 0.8460
Epoch 8/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4046 - accuracy: 0.8599
- val_loss: 0.4542 - val_accuracy: 0.8442
Epoch 9/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4036 - accuracy: 0.8587
- val_loss: 0.4506 - val_accuracy: 0.8454
Epoch 10/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4036 - accuracy: 0.8589
- val_loss: 0.4178 - val_accuracy: 0.8601
Epoch 11/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3994 - accuracy: 0.8602
- val_loss: 0.4259 - val_accuracy: 0.8540
Epoch 12/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4009 - accuracy: 0.8591
- val_loss: 0.4268 - val_accuracy: 0.8574
Epoch 13/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3921 - accuracy: 0.8617
- val_loss: 0.4434 - val_accuracy: 0.8488
Epoch 14/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3966 - accuracy: 0.8599
- val_loss: 0.4378 - val_accuracy: 0.8509
Epoch 15/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3914 - accuracy: 0.8622
- val_loss: 0.4429 - val_accuracy: 0.8494
Epoch 16/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3902 - accuracy: 0.8613
- val_loss: 0.4413 - val_accuracy: 0.8515
Epoch 17/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3906 - accuracy: 0.8622
- val_loss: 0.4370 - val_accuracy: 0.8507
Epoch 18/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3850 - accuracy: 0.8639
- val_loss: 0.4409 - val_accuracy: 0.8483
Epoch 19/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3853 - accuracy: 0.8643
- val_loss: 0.4487 - val_accuracy: 0.8504
Epoch 20/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3815 - accuracy: 0.8652
- val_loss: 0.4346 - val_accuracy: 0.8517
Epoch 21/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3825 - accuracy: 0.8639
- val_loss: 0.4398 - val_accuracy: 0.8505
Epoch 22/100
```

Epoch 22/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3820 - accuracy: 0.8647
- val_loss: 0.4483 - val_accuracy: 0.8517
Epoch 23/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3792 - accuracy: 0.8653
- val_loss: 0.4518 - val_accuracy: 0.8467
Epoch 24/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3786 - accuracy: 0.8663
- val_loss: 0.4302 - val_accuracy: 0.8555
Epoch 25/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3750 - accuracy: 0.8670
- val_loss: 0.4362 - val_accuracy: 0.8529
Epoch 26/100
315/315 [==============================] - 3s 9ms/step - loss: 0.3754 - accuracy: 0.8670
- val_loss: 0.4470 - val_accuracy: 0.8507
Epoch 27/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3762 - accuracy: 0.8656
- val_loss: 0.4363 - val_accuracy: 0.8529
Epoch 28/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3752 - accuracy: 0.8670
- val_loss: 0.4326 - val_accuracy: 0.8535
Epoch 29/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3740 - accuracy: 0.8674
- val_loss: 0.4402 - val_accuracy: 0.8526
Epoch 30/100
315/315 [==============================] - 1s 5ms/step - loss: 0.3731 - accuracy: 0.8675
- val_loss: 0.4625 - val_accuracy: 0.8479
Epoch 31/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3701 - accuracy: 0.8688
- val_loss: 0.4425 - val_accuracy: 0.8540
Epoch 32/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3724 - accuracy: 0.8684
- val_loss: 0.4881 - val_accuracy: 0.8369
Epoch 33/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3695 - accuracy: 0.8688
- val_loss: 0.4281 - val_accuracy: 0.8555
Epoch 34/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3676 - accuracy: 0.8693
- val_loss: 0.4738 - val_accuracy: 0.8409
Epoch 35/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3685 - accuracy: 0.8694
- val_loss: 0.4342 - val_accuracy: 0.8551
Epoch 36/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3666 - accuracy: 0.8688
- val_loss: 0.4338 - val_accuracy: 0.8530
Epoch 37/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3684 - accuracy: 0.8691
- val_loss: 0.4528 - val_accuracy: 0.8534
Epoch 38/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3689 - accuracy: 0.8689
- val_loss: 0.4624 - val_accuracy: 0.8483
Epoch 39/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3647 - accuracy: 0.8702
- val_loss: 0.4412 - val_accuracy: 0.8544
Epoch 40/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3653 - accuracy: 0.8708
- val_loss: 0.4490 - val_accuracy: 0.8488
Epoch 41/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3675 - accuracy: 0.8669
- val_loss: 0.4300 - val_accuracy: 0.8567
Epoch 42/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3658 - accuracy: 0.8682
- val_loss: 0.4520 - val_accuracy: 0.8531
Epoch 43/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3616 - accuracy: 0.8713
- val_loss: 0.4619 - val_accuracy: 0.8461
Epoch 44/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3582 - accuracy: 0.8731
- val_loss: 0.4663 - val_accuracy: 0.8401
Epoch 45/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3640 - accuracy: 0.8702
- val_loss: 0.4455 - val_accuracy: 0.8539
Epoch 46/100

Epoch 46/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3630 - accuracy: 0.8712
- val_loss: 0.4381 - val_accuracy: 0.8551
Epoch 47/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3608 - accuracy: 0.8718
- val_loss: 0.4375 - val_accuracy: 0.8529
Epoch 48/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3588 - accuracy: 0.8718
- val_loss: 0.4401 - val_accuracy: 0.8541
Epoch 49/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3579 - accuracy: 0.8723
- val_loss: 0.4463 - val_accuracy: 0.8527
Epoch 50/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3590 - accuracy: 0.8719
- val_loss: 0.4524 - val_accuracy: 0.8462
Epoch 51/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3583 - accuracy: 0.8718
- val_loss: 0.4585 - val_accuracy: 0.8459
Epoch 52/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3585 - accuracy: 0.8718
- val_loss: 0.4523 - val_accuracy: 0.8530
Epoch 53/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3569 - accuracy: 0.8734
- val_loss: 0.4447 - val_accuracy: 0.8523
Epoch 54/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3585 - accuracy: 0.8725
- val_loss: 0.4544 - val_accuracy: 0.8450
Epoch 55/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3558 - accuracy: 0.8732
- val_loss: 0.4538 - val_accuracy: 0.8494
Epoch 56/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3576 - accuracy: 0.8725
- val_loss: 0.4531 - val_accuracy: 0.8493
Epoch 57/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3595 - accuracy: 0.8731
- val_loss: 0.4399 - val_accuracy: 0.8546
Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3569 - accuracy: 0.8727
- val_loss: 0.4503 - val_accuracy: 0.8525
Epoch 59/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3551 - accuracy: 0.8732
- val_loss: 0.4807 - val_accuracy: 0.8396
Epoch 60/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3592 - accuracy: 0.8724
- val_loss: 0.4577 - val_accuracy: 0.8520
Epoch 61/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3538 - accuracy: 0.8742
- val_loss: 0.4660 - val_accuracy: 0.8461
Epoch 62/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3553 - accuracy: 0.8727
- val_loss: 0.4801 - val_accuracy: 0.8443
Epoch 63/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3532 - accuracy: 0.8726
- val_loss: 0.4615 - val_accuracy: 0.8470
Epoch 64/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3536 - accuracy: 0.8730
- val_loss: 0.4463 - val_accuracy: 0.8514
Epoch 65/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3530 - accuracy: 0.8743
- val_loss: 0.4512 - val_accuracy: 0.8527
Epoch 66/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3523 - accuracy: 0.8749
- val_loss: 0.4531 - val_accuracy: 0.8504
Epoch 67/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3530 - accuracy: 0.8736
- val_loss: 0.4509 - val_accuracy: 0.8483
Epoch 68/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3497 - accuracy: 0.8749
- val_loss: 0.4574 - val_accuracy: 0.8542
Epoch 69/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3513 - accuracy: 0.8745
- val_loss: 0.4531 - val_accuracy: 0.8515
Epoch 70/100

Epoch 70/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3519 - accuracy: 0.8738
- val_loss: 0.4509 - val_accuracy: 0.8522
Epoch 71/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3509 - accuracy: 0.8735
- val_loss: 0.4514 - val_accuracy: 0.8531
Epoch 72/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3508 - accuracy: 0.8744
- val_loss: 0.4558 - val_accuracy: 0.8528
Epoch 73/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3482 - accuracy: 0.8757
- val_loss: 0.4607 - val_accuracy: 0.8490
Epoch 74/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3491 - accuracy: 0.8745
- val_loss: 0.4525 - val_accuracy: 0.8522
Epoch 75/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3487 - accuracy: 0.8759
- val_loss: 0.4506 - val_accuracy: 0.8517
Epoch 76/100
315/315 [==============================] - 3s 9ms/step - loss: 0.3498 - accuracy: 0.8763
- val_loss: 0.4471 - val_accuracy: 0.8547
Epoch 77/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3494 - accuracy: 0.8750
- val_loss: 0.4551 - val_accuracy: 0.8535
Epoch 78/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3484 - accuracy: 0.8756
- val_loss: 0.4626 - val_accuracy: 0.8493
Epoch 79/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3438 - accuracy: 0.8781
- val_loss: 0.4524 - val_accuracy: 0.8524
Epoch 80/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3481 - accuracy: 0.8736
- val_loss: 0.4822 - val_accuracy: 0.8398
Epoch 81/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3484 - accuracy: 0.8752
- val_loss: 0.4699 - val_accuracy: 0.8459
Epoch 82/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3441 - accuracy: 0.8777
- val_loss: 0.4547 - val_accuracy: 0.8499
Epoch 83/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3469 - accuracy: 0.8762
- val_loss: 0.4580 - val_accuracy: 0.8489
Epoch 84/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3476 - accuracy: 0.8750
- val_loss: 0.4528 - val_accuracy: 0.8492
Epoch 85/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3471 - accuracy: 0.8752
- val_loss: 0.4623 - val_accuracy: 0.8486
Epoch 86/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3441 - accuracy: 0.8772
- val_loss: 0.4641 - val_accuracy: 0.8485
Epoch 87/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3437 - accuracy: 0.8771
- val_loss: 0.4542 - val_accuracy: 0.8518
Epoch 88/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3464 - accuracy: 0.8758
- val_loss: 0.4612 - val_accuracy: 0.8529
Epoch 89/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3457 - accuracy: 0.8764
- val_loss: 0.4559 - val_accuracy: 0.8532
Epoch 90/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3429 - accuracy: 0.8781
- val_loss: 0.4678 - val_accuracy: 0.8464
Epoch 91/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3441 - accuracy: 0.8782
- val_loss: 0.4630 - val_accuracy: 0.8484
Epoch 92/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3460 - accuracy: 0.8744
- val_loss: 0.4568 - val_accuracy: 0.8537
Epoch 93/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3476 - accuracy: 0.8746
- val_loss: 0.4551 - val_accuracy: 0.8546
Epoch 94/100

```
Epoch 94/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3444 - accuracy: 0.8768
- val_loss: 0.4796 - val_accuracy: 0.8431
Epoch 95/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3443 - accuracy: 0.8770
- val_loss: 0.4579 - val_accuracy: 0.8539
Epoch 96/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3408 - accuracy: 0.8786
- val_loss: 0.4705 - val_accuracy: 0.8467
Epoch 97/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3442 - accuracy: 0.8766
- val_loss: 0.4543 - val_accuracy: 0.8524
Epoch 98/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3443 - accuracy: 0.8768
- val_loss: 0.4580 - val_accuracy: 0.8523
Epoch 99/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3458 - accuracy: 0.8765
- val_loss: 0.4588 - val_accuracy: 0.8532
Epoch 100/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3400 - accuracy: 0.8780
- val_loss: 0.4815 - val_accuracy: 0.8460
300/300 [==============================] - 1s 2ms/step - loss: 0.4777 - accuracy: 0.8432
Accuracy with learning rate=0.001 is  0.8432291746139526
```

In [ ]:

```
#Building the model with learning rate as 0.01

nn2_model=Sequential()
nn2_model.add(Flatten(input_shape=(28, 28)))
nn2_model.add(Dense(200,activation='linear'))
nn2_model.add(Dense(50,activation='linear'))
nn2_model.add(Dense(10,activation='softmax'))
nn2_model.summary()

#compiling the model using adam optimizer using learning rate 0.01
nn2_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.01), metrics=['ac
curacy'])
lr2_model=nn2_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)

#accuracy using validation set
val_loss, val_acc2=nn2_model.evaluate(X_val, y_val)
accuracy_val[val_acc2]=0.01
print("Accuracy with learning rate=0.01 is ", val_acc2)
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_4 (Flatten)         (None, 784)               0

 dense_12 (Dense)            (None, 200)               157000

 dense_13 (Dense)            (None, 50)                10050

 dense_14 (Dense)            (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
Epoch 1/100
315/315 [==============================] - 3s 6ms/step - loss: 1.3109 - accuracy: 0.7686
- val_loss: 0.4985 - val_accuracy: 0.8284
Epoch 2/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4972 - accuracy: 0.8275
- val_loss: 0.5104 - val_accuracy: 0.8267
Epoch 3/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4790 - accuracy: 0.8329
- val_loss: 0.4546 - val_accuracy: 0.8490
Epoch 4/100
```

```
Epoch 4/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4764 - accuracy: 0.8331
- val_loss: 0.4761 - val_accuracy: 0.8339
Epoch 5/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4572 - accuracy: 0.8415
- val_loss: 0.4725 - val_accuracy: 0.8429
Epoch 6/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4609 - accuracy: 0.8386
- val_loss: 0.4506 - val_accuracy: 0.8422
Epoch 7/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4584 - accuracy: 0.8394
- val_loss: 0.4750 - val_accuracy: 0.8303
Epoch 8/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4633 - accuracy: 0.8384
- val_loss: 0.4829 - val_accuracy: 0.8289
Epoch 9/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4679 - accuracy: 0.8378
- val_loss: 0.5674 - val_accuracy: 0.8066
Epoch 10/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4699 - accuracy: 0.8355
- val_loss: 0.5341 - val_accuracy: 0.8205
Epoch 11/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4721 - accuracy: 0.8369
- val_loss: 0.5580 - val_accuracy: 0.8121
Epoch 12/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4609 - accuracy: 0.8401
- val_loss: 0.4649 - val_accuracy: 0.8444
Epoch 13/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4555 - accuracy: 0.8407
- val_loss: 0.4859 - val_accuracy: 0.8366
Epoch 14/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4604 - accuracy: 0.8401
- val_loss: 0.4594 - val_accuracy: 0.8466
Epoch 15/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4589 - accuracy: 0.8427
- val_loss: 0.5050 - val_accuracy: 0.8315
Epoch 16/100
315/315 [==============================] - 2s 7ms/step - loss: 0.4460 - accuracy: 0.8462
- val_loss: 0.4722 - val_accuracy: 0.8426
Epoch 17/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4475 - accuracy: 0.8431
- val_loss: 0.4771 - val_accuracy: 0.8366
Epoch 18/100
315/315 [==============================] - 2s 7ms/step - loss: 0.4591 - accuracy: 0.8412
- val_loss: 0.4871 - val_accuracy: 0.8413
Epoch 19/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4548 - accuracy: 0.8421
- val_loss: 0.4938 - val_accuracy: 0.8324
Epoch 20/100
315/315 [==============================] - 2s 5ms/step - loss: 7.9373 - accuracy: 0.7735
- val_loss: 1.4891 - val_accuracy: 0.8057
Epoch 21/100
315/315 [==============================] - 2s 5ms/step - loss: 0.7369 - accuracy: 0.8396
- val_loss: 0.6909 - val_accuracy: 0.8322
Epoch 22/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4864 - accuracy: 0.8507
- val_loss: 0.5316 - val_accuracy: 0.8391
Epoch 23/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4424 - accuracy: 0.8539
- val_loss: 0.5118 - val_accuracy: 0.8441
Epoch 24/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4169 - accuracy: 0.8591
- val_loss: 0.4974 - val_accuracy: 0.8504
Epoch 25/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4078 - accuracy: 0.8611
- val_loss: 0.4927 - val_accuracy: 0.8447
Epoch 26/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4039 - accuracy: 0.8602
- val_loss: 0.4939 - val_accuracy: 0.8473
Epoch 27/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4009 - accuracy: 0.8606
- val_loss: 0.4930 - val_accuracy: 0.8477
Epoch 28/100
```

Epoch 28/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3987 - accuracy: 0.8622
- val_loss: 0.4865 - val_accuracy: 0.8434
Epoch 29/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3980 - accuracy: 0.8621
- val_loss: 0.4854 - val_accuracy: 0.8401
Epoch 30/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3998 - accuracy: 0.8611
- val_loss: 0.4749 - val_accuracy: 0.8512
Epoch 31/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4147 - accuracy: 0.8556
- val_loss: 0.4647 - val_accuracy: 0.8461
Epoch 32/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4119 - accuracy: 0.8577
- val_loss: 0.4760 - val_accuracy: 0.8510
Epoch 33/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4034 - accuracy: 0.8601
- val_loss: 0.5082 - val_accuracy: 0.8331
Epoch 34/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4033 - accuracy: 0.8581
- val_loss: 0.4875 - val_accuracy: 0.8389
Epoch 35/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4217 - accuracy: 0.8524
- val_loss: 0.5206 - val_accuracy: 0.8374
Epoch 36/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4220 - accuracy: 0.8525
- val_loss: 0.4989 - val_accuracy: 0.8354
Epoch 37/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4192 - accuracy: 0.8527
- val_loss: 0.4952 - val_accuracy: 0.8407
Epoch 38/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4150 - accuracy: 0.8550
- val_loss: 0.4866 - val_accuracy: 0.8375
Epoch 39/100
315/315 [==============================] - 2s 7ms/step - loss: 0.4129 - accuracy: 0.8544
- val_loss: 0.4965 - val_accuracy: 0.8411
Epoch 40/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4298 - accuracy: 0.8494
- val_loss: 0.5297 - val_accuracy: 0.8166
Epoch 41/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4335 - accuracy: 0.8494
- val_loss: 0.5025 - val_accuracy: 0.8409
Epoch 42/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4234 - accuracy: 0.8531
- val_loss: 0.5019 - val_accuracy: 0.8308
Epoch 43/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4435 - accuracy: 0.8470
- val_loss: 0.4940 - val_accuracy: 0.8436
Epoch 44/100
315/315 [==============================] - 2s 5ms/step - loss: 0.5459 - accuracy: 0.8305
- val_loss: 0.5630 - val_accuracy: 0.8285
Epoch 45/100
315/315 [==============================] - 1s 5ms/step - loss: 0.4201 - accuracy: 0.8553
- val_loss: 0.4797 - val_accuracy: 0.8456
Epoch 46/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4018 - accuracy: 0.8591
- val_loss: 0.4716 - val_accuracy: 0.8450
Epoch 47/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4244 - accuracy: 0.8509
- val_loss: 0.5169 - val_accuracy: 0.8315
Epoch 48/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4255 - accuracy: 0.8530
- val_loss: 0.5083 - val_accuracy: 0.8281
Epoch 49/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4312 - accuracy: 0.8496
- val_loss: 0.5541 - val_accuracy: 0.8194
Epoch 50/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4303 - accuracy: 0.8508
- val_loss: 0.5332 - val_accuracy: 0.8365
Epoch 51/100
315/315 [==============================] - 2s 5ms/step - loss: 7.5142 - accuracy: 0.7815
- val_loss: 1.2369 - val_accuracy: 0.8147
Epoch 52/100

Epoch 52/100
315/315 [==============================] - 2s 5ms/step - loss: 0.5961 - accuracy: 0.8504
- val_loss: 0.6181 - val_accuracy: 0.8355
Epoch 53/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4414 - accuracy: 0.8586
- val_loss: 0.5609 - val_accuracy: 0.8370
Epoch 54/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4030 - accuracy: 0.8633
- val_loss: 0.5392 - val_accuracy: 0.8413
Epoch 55/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4049 - accuracy: 0.8628
- val_loss: 0.5084 - val_accuracy: 0.8417
Epoch 56/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3865 - accuracy: 0.8644
- val_loss: 0.4900 - val_accuracy: 0.8496
Epoch 57/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3795 - accuracy: 0.8662
- val_loss: 0.5269 - val_accuracy: 0.8376
Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3851 - accuracy: 0.8651
- val_loss: 0.4969 - val_accuracy: 0.8478
Epoch 59/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3813 - accuracy: 0.8656
- val_loss: 0.5045 - val_accuracy: 0.8350
Epoch 60/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3842 - accuracy: 0.8662
- val_loss: 0.4971 - val_accuracy: 0.8379
Epoch 61/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3888 - accuracy: 0.8622
- val_loss: 0.5119 - val_accuracy: 0.8353
Epoch 62/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3912 - accuracy: 0.8616
- val_loss: 0.5023 - val_accuracy: 0.8374
Epoch 63/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3869 - accuracy: 0.8638
- val_loss: 0.4836 - val_accuracy: 0.8397
Epoch 64/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3926 - accuracy: 0.8619
- val_loss: 0.5010 - val_accuracy: 0.8441
Epoch 65/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4047 - accuracy: 0.8585
- val_loss: 0.5393 - val_accuracy: 0.8281
Epoch 66/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4051 - accuracy: 0.8568
- val_loss: 0.4702 - val_accuracy: 0.8484
Epoch 67/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3965 - accuracy: 0.8610
- val_loss: 0.4739 - val_accuracy: 0.8475
Epoch 68/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4031 - accuracy: 0.8564
- val_loss: 0.5059 - val_accuracy: 0.8349
Epoch 69/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4045 - accuracy: 0.8584
- val_loss: 0.4761 - val_accuracy: 0.8484
Epoch 70/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4049 - accuracy: 0.8570
- val_loss: 0.4830 - val_accuracy: 0.8436
Epoch 71/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4191 - accuracy: 0.8538
- val_loss: 0.5250 - val_accuracy: 0.8359
Epoch 72/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4218 - accuracy: 0.8541
- val_loss: 0.5440 - val_accuracy: 0.8151
Epoch 73/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4060 - accuracy: 0.8562
- val_loss: 0.5276 - val_accuracy: 0.8290
Epoch 74/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4160 - accuracy: 0.8538
- val_loss: 0.5524 - val_accuracy: 0.8237
Epoch 75/100
315/315 [==============================] - 3s 8ms/step - loss: 0.4286 - accuracy: 0.8526
- val_loss: 0.5250 - val_accuracy: 0.8336
Epoch 76/100

Epoch 76/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4288 - accuracy: 0.8512
- val_loss: 0.5184 - val_accuracy: 0.8344
Epoch 77/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4346 - accuracy: 0.8506
- val_loss: 0.5133 - val_accuracy: 0.8332
Epoch 78/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4201 - accuracy: 0.8528
- val_loss: 0.5215 - val_accuracy: 0.8382
Epoch 79/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4309 - accuracy: 0.8509
- val_loss: 0.5325 - val_accuracy: 0.8340
Epoch 80/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4760 - accuracy: 0.8406
- val_loss: 0.6274 - val_accuracy: 0.8141
Epoch 81/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4332 - accuracy: 0.8536
- val_loss: 0.4952 - val_accuracy: 0.8393
Epoch 82/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3986 - accuracy: 0.8601
- val_loss: 0.5426 - val_accuracy: 0.8266
Epoch 83/100
315/315 [==============================] - 2s 7ms/step - loss: 0.4106 - accuracy: 0.8565
- val_loss: 0.6191 - val_accuracy: 0.8082
Epoch 84/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4564 - accuracy: 0.8462
- val_loss: 0.5101 - val_accuracy: 0.8403
Epoch 85/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4342 - accuracy: 0.8506
- val_loss: 0.5400 - val_accuracy: 0.8308
Epoch 86/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4056 - accuracy: 0.8586
- val_loss: 0.5294 - val_accuracy: 0.8343
Epoch 87/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4467 - accuracy: 0.8472
- val_loss: 0.6949 - val_accuracy: 0.8095
Epoch 88/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4148 - accuracy: 0.8567
- val_loss: 0.5195 - val_accuracy: 0.8344
Epoch 89/100
315/315 [==============================] - 2s 6ms/step - loss: 0.4130 - accuracy: 0.8551
- val_loss: 0.5254 - val_accuracy: 0.8346
Epoch 90/100
315/315 [==============================] - 2s 8ms/step - loss: 0.4807 - accuracy: 0.8400
- val_loss: 0.5398 - val_accuracy: 0.8366
Epoch 91/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3930 - accuracy: 0.8606
- val_loss: 0.5006 - val_accuracy: 0.8403
Epoch 92/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3950 - accuracy: 0.8590
- val_loss: 0.5092 - val_accuracy: 0.8373
Epoch 93/100
315/315 [==============================] - 2s 6ms/step - loss: 4.4808 - accuracy: 0.7935
- val_loss: 1.0769 - val_accuracy: 0.8298
Epoch 94/100
315/315 [==============================] - 2s 5ms/step - loss: 0.5075 - accuracy: 0.8554
- val_loss: 0.6255 - val_accuracy: 0.8350
Epoch 95/100
315/315 [==============================] - 2s 5ms/step - loss: 0.4120 - accuracy: 0.8621
- val_loss: 0.5699 - val_accuracy: 0.8386
Epoch 96/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3861 - accuracy: 0.8669
- val_loss: 0.5430 - val_accuracy: 0.8406
Epoch 97/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3783 - accuracy: 0.8679
- val_loss: 0.5126 - val_accuracy: 0.8401
Epoch 98/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3734 - accuracy: 0.8691
- val_loss: 0.5049 - val_accuracy: 0.8475
Epoch 99/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3766 - accuracy: 0.8675
- val_loss: 0.5279 - val_accuracy: 0.8435
Epoch 100/100

```
Epoch 100/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3765 - accuracy: 0.8667
- val_loss: 0.5037 - val_accuracy: 0.8392
300/300 [==============================] - 1s 2ms/step - loss: 0.5053 - accuracy: 0.8408
Accuracy with learning rate=0.01 is  0.840833306312561
```

In [ ]:

```
#Building the model with learning rate as 0.1

nn3_model=Sequential()
nn3_model.add(Flatten(input_shape=(28, 28)))
nn3_model.add(Dense(200,activation='linear'))
nn3_model.add(Dense(50,activation='linear'))
nn3_model.add(Dense(10,activation='softmax'))
nn3_model.summary()

#compiling the model using adam optimizer using learning rate 0.1
nn3_model.compile(loss='categorical_crossentropy', optimizer=Adam(lr=0.1), metrics=['acc
uracy'])
lr3_model=nn1_model.fit(X_train, y_train, epochs=100, batch_size=128, validation_split=0
.2, verbose=1)

#accuracy using validation set
val_loss, val_acc3=nn3_model.evaluate(X_val, y_val)
accuracy_val[val_acc3]=0.1
print("Accuracy with learning rate=0.1 is ", val_acc3)
```

```
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 flatten_6 (Flatten)         (None, 784)               0

 dense_18 (Dense)            (None, 200)               157000

 dense_19 (Dense)            (None, 50)                10050

 dense_20 (Dense)            (None, 10)                510

=================================================================
Total params: 167,560
Trainable params: 167,560
Non-trainable params: 0
_________________________________________________________________
Epoch 1/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3285 - accuracy: 0.8801
- val_loss: 0.4882 - val_accuracy: 0.8477
Epoch 2/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3303 - accuracy: 0.8806
- val_loss: 0.4980 - val_accuracy: 0.8444
Epoch 3/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3270 - accuracy: 0.8833
- val_loss: 0.4871 - val_accuracy: 0.8481
Epoch 4/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3289 - accuracy: 0.8826
- val_loss: 0.4849 - val_accuracy: 0.8513
Epoch 5/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3289 - accuracy: 0.8820
- val_loss: 0.4848 - val_accuracy: 0.8490
Epoch 6/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3290 - accuracy: 0.8816
- val_loss: 0.4881 - val_accuracy: 0.8480
Epoch 7/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3268 - accuracy: 0.8820
- val_loss: 0.4928 - val_accuracy: 0.8461
Epoch 8/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3287 - accuracy: 0.8818
- val_loss: 0.4913 - val_accuracy: 0.8474
Epoch 9/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3251 - accuracy: 0.8829
- val_loss: 0.4876 - val_accuracy: 0.8471
Epoch 10/100
```

Epoch 10/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3281 - accuracy: 0.8828
- val_loss: 0.4927 - val_accuracy: 0.8469
Epoch 11/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3290 - accuracy: 0.8795
- val_loss: 0.4920 - val_accuracy: 0.8467
Epoch 12/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3263 - accuracy: 0.8830
- val_loss: 0.4941 - val_accuracy: 0.8455
Epoch 13/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3277 - accuracy: 0.8819
- val_loss: 0.4910 - val_accuracy: 0.8460
Epoch 14/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3316 - accuracy: 0.8806
- val_loss: 0.4951 - val_accuracy: 0.8463
Epoch 15/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3278 - accuracy: 0.8821
- val_loss: 0.4857 - val_accuracy: 0.8475
Epoch 16/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3247 - accuracy: 0.8823
- val_loss: 0.4976 - val_accuracy: 0.8453
Epoch 17/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3269 - accuracy: 0.8819
- val_loss: 0.4887 - val_accuracy: 0.8458
Epoch 18/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3263 - accuracy: 0.8815
- val_loss: 0.4928 - val_accuracy: 0.8461
Epoch 19/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3260 - accuracy: 0.8818
- val_loss: 0.4889 - val_accuracy: 0.8481
Epoch 20/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3239 - accuracy: 0.8843
- val_loss: 0.5126 - val_accuracy: 0.8452
Epoch 21/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3269 - accuracy: 0.8825
- val_loss: 0.4940 - val_accuracy: 0.8491
Epoch 22/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3278 - accuracy: 0.8821
- val_loss: 0.4862 - val_accuracy: 0.8489
Epoch 23/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3260 - accuracy: 0.8832
- val_loss: 0.4970 - val_accuracy: 0.8446
Epoch 24/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3252 - accuracy: 0.8831
- val_loss: 0.4952 - val_accuracy: 0.8437
Epoch 25/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3284 - accuracy: 0.8822
- val_loss: 0.4975 - val_accuracy: 0.8491
Epoch 26/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3266 - accuracy: 0.8831
- val_loss: 0.4993 - val_accuracy: 0.8486
Epoch 27/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3290 - accuracy: 0.8799
- val_loss: 0.5159 - val_accuracy: 0.8378
Epoch 28/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3261 - accuracy: 0.8827
- val_loss: 0.4957 - val_accuracy: 0.8446
Epoch 29/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3267 - accuracy: 0.8819
- val_loss: 0.4916 - val_accuracy: 0.8464
Epoch 30/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3264 - accuracy: 0.8829
- val_loss: 0.4897 - val_accuracy: 0.8487
Epoch 31/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3260 - accuracy: 0.8823
- val_loss: 0.5060 - val_accuracy: 0.8447
Epoch 32/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3262 - accuracy: 0.8810
- val_loss: 0.5065 - val_accuracy: 0.8424
Epoch 33/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3252 - accuracy: 0.8818
- val_loss: 0.4956 - val_accuracy: 0.8463
Epoch 34/100

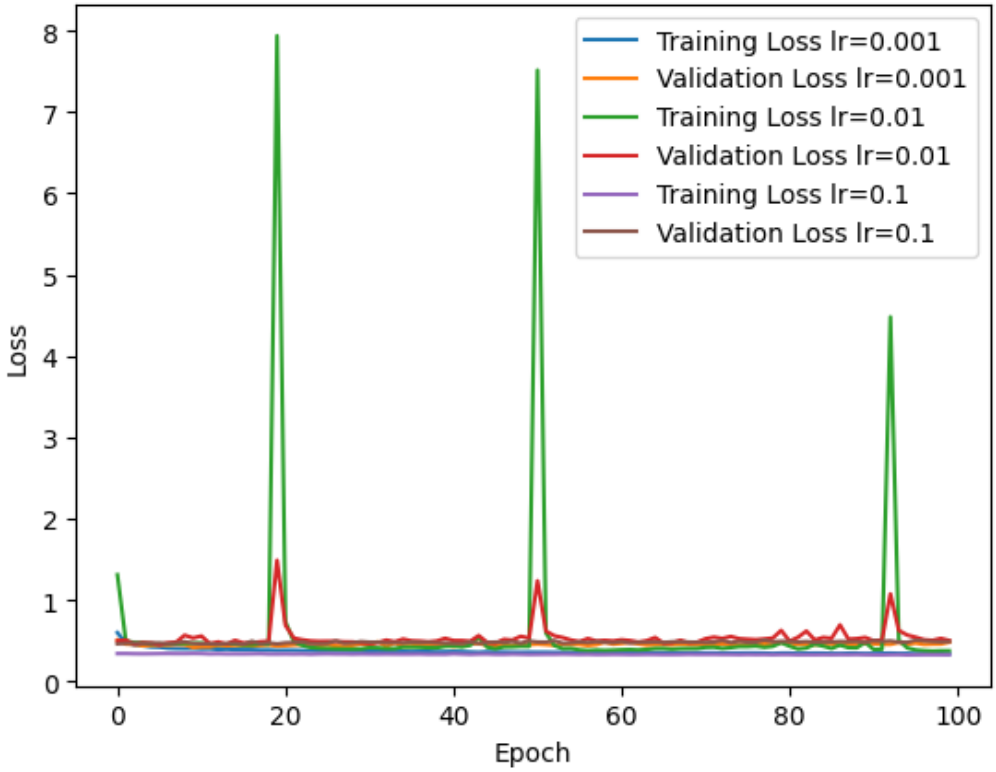
Epoch 34/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3246 - accuracy: 0.8833
- val_loss: 0.4954 - val_accuracy: 0.8465
Epoch 35/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3267 - accuracy: 0.8824
- val_loss: 0.4941 - val_accuracy: 0.8476
Epoch 36/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3268 - accuracy: 0.8808
- val_loss: 0.4934 - val_accuracy: 0.8457
Epoch 37/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3245 - accuracy: 0.8831
- val_loss: 0.5008 - val_accuracy: 0.8464
Epoch 38/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3255 - accuracy: 0.8826
- val_loss: 0.5019 - val_accuracy: 0.8450
Epoch 39/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3253 - accuracy: 0.8832
- val_loss: 0.4999 - val_accuracy: 0.8444
Epoch 40/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3244 - accuracy: 0.8831
- val_loss: 0.4976 - val_accuracy: 0.8471
Epoch 41/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3245 - accuracy: 0.8840
- val_loss: 0.5142 - val_accuracy: 0.8420
Epoch 42/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3262 - accuracy: 0.8828
- val_loss: 0.4956 - val_accuracy: 0.8483
Epoch 43/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3230 - accuracy: 0.8836
- val_loss: 0.5052 - val_accuracy: 0.8466
Epoch 44/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3251 - accuracy: 0.8836
- val_loss: 0.4886 - val_accuracy: 0.8482
Epoch 45/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3253 - accuracy: 0.8844
- val_loss: 0.5055 - val_accuracy: 0.8495
Epoch 46/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3248 - accuracy: 0.8822
- val_loss: 0.5076 - val_accuracy: 0.8438
Epoch 47/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3258 - accuracy: 0.8834
- val_loss: 0.4898 - val_accuracy: 0.8490
Epoch 48/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3255 - accuracy: 0.8823
- val_loss: 0.4937 - val_accuracy: 0.8475
Epoch 49/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3268 - accuracy: 0.8824
- val_loss: 0.5018 - val_accuracy: 0.8475
Epoch 50/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3243 - accuracy: 0.8834
- val_loss: 0.5195 - val_accuracy: 0.8401
Epoch 51/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3262 - accuracy: 0.8834
- val_loss: 0.4881 - val_accuracy: 0.8501
Epoch 52/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3223 - accuracy: 0.8843
- val_loss: 0.4942 - val_accuracy: 0.8491
Epoch 53/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3237 - accuracy: 0.8838
- val_loss: 0.5042 - val_accuracy: 0.8476
Epoch 54/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3234 - accuracy: 0.8832
- val_loss: 0.5041 - val_accuracy: 0.8469
Epoch 55/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3245 - accuracy: 0.8835
- val_loss: 0.5171 - val_accuracy: 0.8398
Epoch 56/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3261 - accuracy: 0.8835
- val_loss: 0.4927 - val_accuracy: 0.8490
Epoch 57/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3246 - accuracy: 0.8819
- val_loss: 0.4998 - val_accuracy: 0.8444
Epoch 58/100

Epoch 58/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3243 - accuracy: 0.8834
- val_loss: 0.5061 - val_accuracy: 0.8425
Epoch 59/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3250 - accuracy: 0.8819
- val_loss: 0.4928 - val_accuracy: 0.8474
Epoch 60/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3248 - accuracy: 0.8832
- val_loss: 0.4973 - val_accuracy: 0.8475
Epoch 61/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3267 - accuracy: 0.8827
- val_loss: 0.5071 - val_accuracy: 0.8453
Epoch 62/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3255 - accuracy: 0.8817
- val_loss: 0.4929 - val_accuracy: 0.8474
Epoch 63/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3228 - accuracy: 0.8842
- val_loss: 0.4929 - val_accuracy: 0.8474
Epoch 64/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3230 - accuracy: 0.8837
- val_loss: 0.4986 - val_accuracy: 0.8474
Epoch 65/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3224 - accuracy: 0.8837
- val_loss: 0.5210 - val_accuracy: 0.8424
Epoch 66/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3252 - accuracy: 0.8830
- val_loss: 0.4957 - val_accuracy: 0.8458
Epoch 67/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3228 - accuracy: 0.8835
- val_loss: 0.5070 - val_accuracy: 0.8438
Epoch 68/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3239 - accuracy: 0.8830
- val_loss: 0.4967 - val_accuracy: 0.8444
Epoch 69/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3230 - accuracy: 0.8833
- val_loss: 0.4960 - val_accuracy: 0.8493
Epoch 70/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3272 - accuracy: 0.8815
- val_loss: 0.5119 - val_accuracy: 0.8424
Epoch 71/100
315/315 [==============================] - 3s 8ms/step - loss: 0.3236 - accuracy: 0.8832
- val_loss: 0.5007 - val_accuracy: 0.8443
Epoch 72/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3233 - accuracy: 0.8832
- val_loss: 0.4997 - val_accuracy: 0.8458
Epoch 73/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3258 - accuracy: 0.8823
- val_loss: 0.4937 - val_accuracy: 0.8490
Epoch 74/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3234 - accuracy: 0.8828
- val_loss: 0.4991 - val_accuracy: 0.8493
Epoch 75/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3235 - accuracy: 0.8834
- val_loss: 0.5064 - val_accuracy: 0.8475
Epoch 76/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3224 - accuracy: 0.8846
- val_loss: 0.5148 - val_accuracy: 0.8434
Epoch 77/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3235 - accuracy: 0.8843
- val_loss: 0.5099 - val_accuracy: 0.8451
Epoch 78/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3245 - accuracy: 0.8828
- val_loss: 0.5048 - val_accuracy: 0.8440
Epoch 79/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3253 - accuracy: 0.8835
- val_loss: 0.4957 - val_accuracy: 0.8472
Epoch 80/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3196 - accuracy: 0.8849
- val_loss: 0.5283 - val_accuracy: 0.8370
Epoch 81/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3219 - accuracy: 0.8835
- val_loss: 0.5072 - val_accuracy: 0.8438
Epoch 82/100

```
Epoch 82/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3234 - accuracy: 0.8843
- val_loss: 0.5029 - val_accuracy: 0.8456
Epoch 83/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3233 - accuracy: 0.8844
- val_loss: 0.5006 - val_accuracy: 0.8481
Epoch 84/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3232 - accuracy: 0.8826
- val_loss: 0.5064 - val_accuracy: 0.8418
Epoch 85/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3230 - accuracy: 0.8831
- val_loss: 0.5100 - val_accuracy: 0.8422
Epoch 86/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3241 - accuracy: 0.8839
- val_loss: 0.5027 - val_accuracy: 0.8474
Epoch 87/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3230 - accuracy: 0.8848
- val_loss: 0.5068 - val_accuracy: 0.8420
Epoch 88/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3214 - accuracy: 0.8842
- val_loss: 0.5092 - val_accuracy: 0.8440
Epoch 89/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3231 - accuracy: 0.8843
- val_loss: 0.5027 - val_accuracy: 0.8466
Epoch 90/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3213 - accuracy: 0.8847
- val_loss: 0.5193 - val_accuracy: 0.8435
Epoch 91/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3222 - accuracy: 0.8844
- val_loss: 0.4987 - val_accuracy: 0.8482
Epoch 92/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3221 - accuracy: 0.8838
- val_loss: 0.5081 - val_accuracy: 0.8457
Epoch 93/100
315/315 [==============================] - 2s 7ms/step - loss: 0.3219 - accuracy: 0.8837
- val_loss: 0.5025 - val_accuracy: 0.8453
Epoch 94/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3220 - accuracy: 0.8842
- val_loss: 0.5056 - val_accuracy: 0.8432
Epoch 95/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3223 - accuracy: 0.8843
- val_loss: 0.5104 - val_accuracy: 0.8439
Epoch 96/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3239 - accuracy: 0.8834
- val_loss: 0.5037 - val_accuracy: 0.8465
Epoch 97/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3210 - accuracy: 0.8849
- val_loss: 0.5254 - val_accuracy: 0.8409
Epoch 98/100
315/315 [==============================] - 2s 5ms/step - loss: 0.3234 - accuracy: 0.8854
- val_loss: 0.5008 - val_accuracy: 0.8474
Epoch 99/100
315/315 [==============================] - 2s 8ms/step - loss: 0.3241 - accuracy: 0.8820
- val_loss: 0.5080 - val_accuracy: 0.8456
Epoch 100/100
315/315 [==============================] - 2s 6ms/step - loss: 0.3206 - accuracy: 0.8850
- val_loss: 0.5021 - val_accuracy: 0.8464
300/300 [==============================] - 1s 2ms/step - loss: 2.7502 - accuracy: 0.0550
Accuracy with learning rate=0.1 is  0.054999999701976776
```

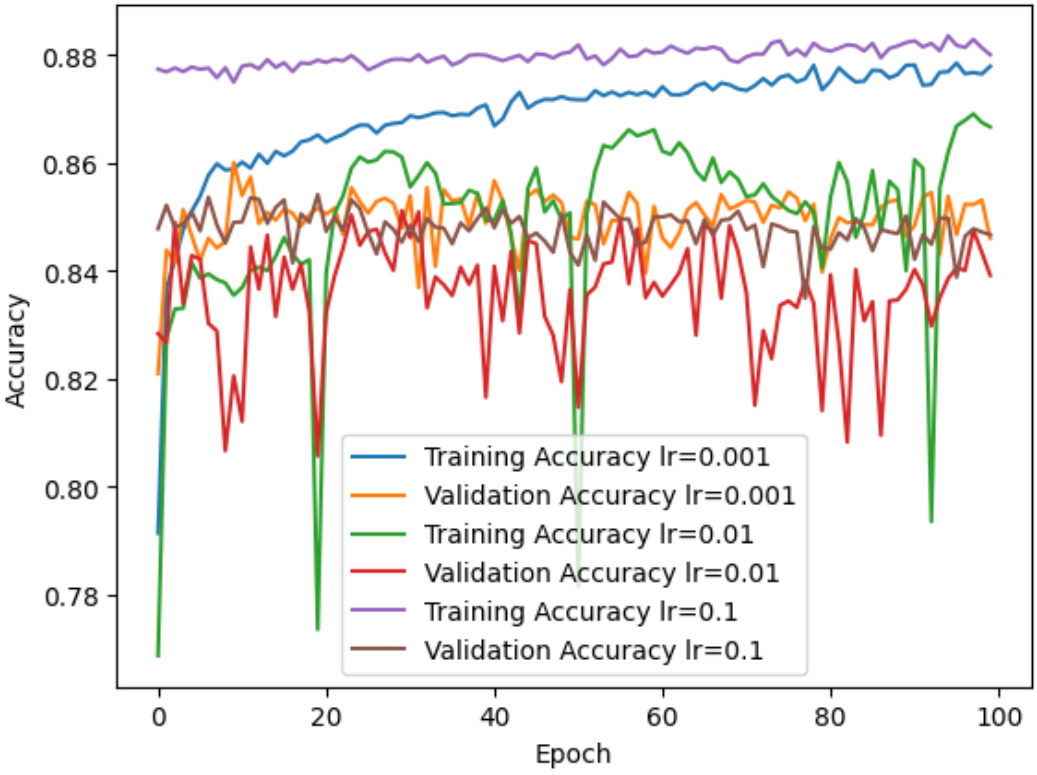
In [ ]:

```
plt.plot(lr1_model.history['loss'], label='Training Loss lr=0.001')
plt.plot(lr1_model.history['val_loss'], label='Validation Loss lr=0.001')
plt.plot(lr2_model.history['loss'], label='Training Loss lr=0.01')
plt.plot(lr2_model.history['val_loss'], label='Validation Loss lr=0.01')
plt.plot(lr3_model.history['loss'], label='Training Loss lr=0.1')
plt.plot(lr3_model.history['val_loss'], label='Validation Loss lr=0.1')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



In [ ]:

```
plt.plot(lr1_model.history['accuracy'], label='Training Accuracy lr=0.001')
plt.plot(lr1_model.history['val_accuracy'], label='Validation Accuracy lr=0.001')
plt.plot(lr2_model.history['accuracy'], label='Training Accuracy lr=0.01')
plt.plot(lr2_model.history['val_accuracy'], label='Validation Accuracy lr=0.01')
plt.plot(lr3_model.history['accuracy'], label='Training Accuracy lr=0.1')
plt.plot(lr3_model.history['val_accuracy'], label='Validation Accuracy lr=0.1')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



In [ ]:

```
#Accuracy and loss using the testing set
max_lr=max(accuracy_val.keys())
```

```
if max_lr==val_acc1:
  loss, accuracy=nn1_model.evaluate(X_test, y_test)
elif max_lr==val_acc2:
  loss, accuracy=nn2_model.evaluate(X_test, y_test)
else:
  loss, accuracy=nn3_model.evaluate(X_test, y_test)

print("Learning rate: ", accuracy_val[max_lr])
print("Loss: ", loss)
print("Accuracy: ", accuracy)
```

```
313/313 [==============================] - 1s 2ms/step - loss: 2.4324 - accuracy: 0.0823
Learning rate:  0.001
Loss:  2.4324288368225098
Accuracy:  0.08229999989271164
```

Discuss how this impacts accuracy and why.

We can clearly see that using relu as an activation function over linear results in vastly superior accuracies all over the board.

The models with learning rate 0.001 and 0.01 show a small difference(increase) in accuracy when Relu is considered over the linear activation function but when the learning rate is considered 0.1 then Relu completely destroys the linear activation function.

This may be happening due to relu being more capable of handling negative values that come out as output of that particular layer in the network.