hw01

May 7, 2019

1 Classification using neural networks

1

```
In [1]: import random
        random.seed(1234)
```

2

```
In [1]: from keras.datasets import fashion_mnist
```

```
Using TensorFlow backend.
```

```
In [2]: (x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()
```

```
In [4]: print(x_train.shape)
        print(y_train.shape)
        print(x_test.shape)
        print(y_test.shape)
```

```
(60000, 28, 28)
(60000,)
(10000, 28, 28)
(10000,)
```

```
In [24]: #converting the data to a 2D tensor
         x_train = x_train.reshape([60000, 28*28]).astype('float32')/255
         x_test = x_test.reshape([10000, 28*28]).astype('float32')/255
```

```
In [25]: from keras.utils import to_categorical
```

```
In [26]: #change individual values between 0 and 1
         y_train = to_categorical(y_train)
         y_test = to_categorical(y_test)
```

```
In [27]: from sklearn.model_selection import train_test_split
```

```
In [28]: x_train, x_valid, y_train, y_valid = train_test_split(x_train, y_train, test_size=0.1
```

3

```
In [29]: from keras import models
         from keras import layers
         import tensorflow as tf
```

i. Initial test

```
In [30]: network = models.Sequential()
         network.add(layers.Dense(512, activation='relu', input_shape=(28*28,)))
         network.add(layers.Dense(512, activation='relu'))
         network.add(layers.Dense(512, activation='relu'))
         network.add(layers.Dense(512, activation='relu'))
         network.add(layers.Dense(10, activation='softmax'))
         network.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['accura
         result = network.fit(x_train, y_train, validation_data=(x_valid, y_valid), epochs=200
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.8421 - acc: 0.6953 - val_
Epoch 2/200
50000/50000 [==============================] - 3s 58us/step - loss: 0.5136 - acc: 0.8103 - val_
Epoch 3/200
50000/50000 [==============================] - 3s 58us/step - loss: 0.4292 - acc: 0.8408 - val_
Epoch 4/200
50000/50000 [==============================] - 3s 58us/step - loss: 0.3873 - acc: 0.8546 - val_
Epoch 5/200
50000/50000 [==============================] - 3s 59us/step - loss: 0.3543 - acc: 0.8674 - val_
Epoch 6/200
50000/50000 [==============================] - 3s 58us/step - loss: 0.3290 - acc: 0.8754 - val_
Epoch 7/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.3125 - acc: 0.8839 - val_
Epoch 8/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.2964 - acc: 0.8877 - val_
Epoch 9/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.2792 - acc: 0.8949 - val_
Epoch 10/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.2649 - acc: 0.8978 - val_
Epoch 11/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.2557 - acc: 0.9027 - val_
Epoch 12/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.2484 - acc: 0.9059 - val_
Epoch 13/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.2362 - acc: 0.9096 - val_
Epoch 14/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.2292 - acc: 0.9126 - val_
Epoch 15/200
```

```
50000/50000 [==============================] - 3s 63us/step - loss: 0.2241 - acc: 0.9150 - val
Epoch 16/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.2138 - acc: 0.9191 - val
Epoch 17/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.2064 - acc: 0.9206 - val
Epoch 18/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1979 - acc: 0.9233 - val
Epoch 19/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1985 - acc: 0.9252 - val
Epoch 20/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1871 - acc: 0.9269 - val
Epoch 21/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1839 - acc: 0.9279 - val
Epoch 22/200
50000/50000 [==============================] - 4s 72us/step - loss: 0.1824 - acc: 0.9317 - val
Epoch 23/200
50000/50000 [==============================] - 3s 69us/step - loss: 0.1765 - acc: 0.9326 - val
Epoch 24/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1719 - acc: 0.9332 - val
Epoch 25/200
50000/50000 [==============================] - 4s 73us/step - loss: 0.1739 - acc: 0.9346 - val
Epoch 26/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1638 - acc: 0.9366 - val
Epoch 27/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.1602 - acc: 0.9394 - val
Epoch 28/200
50000/50000 [==============================] - 4s 73us/step - loss: 0.1574 - acc: 0.9396 - val
Epoch 29/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1571 - acc: 0.9412 - val
Epoch 30/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1500 - acc: 0.9420 - val
Epoch 31/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1523 - acc: 0.9425 - val
Epoch 32/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1514 - acc: 0.9443 - val
Epoch 33/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1438 - acc: 0.9454 - val
Epoch 34/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1408 - acc: 0.9459 - val
Epoch 35/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1466 - acc: 0.9457 - val
Epoch 36/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1456 - acc: 0.9481 - val
Epoch 37/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1362 - acc: 0.9489 - val
Epoch 38/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1399 - acc: 0.9487 - val
Epoch 39/200
```

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50000/50000 [==============================] - 3s 64us/step - loss: 0.1369 - acc: 0.9501 - val
Epoch 40/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1478 - acc: 0.9479 - val
Epoch 41/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1338 - acc: 0.9515 - val
Epoch 42/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1302 - acc: 0.9523 - val
Epoch 43/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1346 - acc: 0.9514 - val
Epoch 44/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1274 - acc: 0.9533 - val
Epoch 45/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1237 - acc: 0.9552 - val
Epoch 46/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1257 - acc: 0.9541 - val
Epoch 47/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1285 - acc: 0.9537 - val
Epoch 48/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1228 - acc: 0.9555 - val
Epoch 49/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1307 - acc: 0.9553 - val
Epoch 50/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1227 - acc: 0.9551 - val
Epoch 51/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1251 - acc: 0.9548 - val
Epoch 52/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1242 - acc: 0.9551 - val
Epoch 53/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1164 - acc: 0.9582 - val
Epoch 54/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1147 - acc: 0.9591 - val
Epoch 55/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1168 - acc: 0.9581 - val
Epoch 56/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1177 - acc: 0.9587 - val
Epoch 57/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1189 - acc: 0.9584 - val
Epoch 58/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1149 - acc: 0.9599 - val
Epoch 59/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1182 - acc: 0.9573 - val
Epoch 60/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1167 - acc: 0.9603 - val
Epoch 61/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1136 - acc: 0.9592 - val
Epoch 62/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1112 - acc: 0.9617 - val
Epoch 63/200
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50000/50000 [==============================] - 3s 64us/step - loss: 0.1165 - acc: 0.9615 - val
Epoch 64/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1086 - acc: 0.9626 - val
Epoch 65/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1126 - acc: 0.9615 - val
Epoch 66/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1069 - acc: 0.9628 - val
Epoch 67/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1066 - acc: 0.9625 - val
Epoch 68/200
50000/50000 [==============================] - 3s 68us/step - loss: 0.1061 - acc: 0.9650 - val
Epoch 69/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1143 - acc: 0.9631 - val
Epoch 70/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.1079 - acc: 0.9642 - val
Epoch 71/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0930 - acc: 0.9687 - val
Epoch 72/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1043 - acc: 0.9662 - val
Epoch 73/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1062 - acc: 0.9657 - val
Epoch 74/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0992 - acc: 0.9656 - val
Epoch 75/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1037 - acc: 0.9645 - val
Epoch 76/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0974 - acc: 0.9673 - val
Epoch 77/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0973 - acc: 0.9671 - val
Epoch 78/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0948 - acc: 0.9674 - val
Epoch 79/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1029 - acc: 0.9665 - val
Epoch 80/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0971 - acc: 0.9669 - val
Epoch 81/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0898 - acc: 0.9691 - val
Epoch 82/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0973 - acc: 0.9683 - val
Epoch 83/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0979 - acc: 0.9674 - val
Epoch 84/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0960 - acc: 0.9688 - val
Epoch 85/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.1007 - acc: 0.9664 - val
Epoch 86/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0909 - acc: 0.9694 - val
Epoch 87/200
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50000/50000 [==============================] - 3s 64us/step - loss: 0.0968 - acc: 0.9691 - val
Epoch 88/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1003 - acc: 0.9691 - val
Epoch 89/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0910 - acc: 0.9692 - val
Epoch 90/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0887 - acc: 0.9707 - val
Epoch 91/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0931 - acc: 0.9709 - val
Epoch 92/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0901 - acc: 0.9701 - val
Epoch 93/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0953 - acc: 0.9711 - val
Epoch 94/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0895 - acc: 0.9711 - val
Epoch 95/200
50000/50000 [==============================] - 3s 69us/step - loss: 0.1004 - acc: 0.9689 - val
Epoch 96/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.0888 - acc: 0.9717 - val
Epoch 97/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0839 - acc: 0.9732 - val
Epoch 98/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0865 - acc: 0.9719 - val
Epoch 99/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0888 - acc: 0.9716 - val
Epoch 100/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0841 - acc: 0.9728 - val
Epoch 101/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0963 - acc: 0.9713 - val
Epoch 102/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0897 - acc: 0.9718 - val
Epoch 103/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0908 - acc: 0.9741 - val
Epoch 104/200
50000/50000 [==============================] - 3s 68us/step - loss: 0.0950 - acc: 0.9727 - val
Epoch 105/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.0973 - acc: 0.9725 - val
Epoch 106/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0873 - acc: 0.9732 - val
Epoch 107/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0900 - acc: 0.9731 - val
Epoch 108/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.1008 - acc: 0.9734 - val
Epoch 109/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0872 - acc: 0.9736 - val
Epoch 110/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0802 - acc: 0.9756 - val
Epoch 111/200
```

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50000/50000 [==============================] - 3s 64us/step - loss: 0.0801 - acc: 0.9739 - val
Epoch 112/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0830 - acc: 0.9756 - val
Epoch 113/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0802 - acc: 0.9762 - val
Epoch 114/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0841 - acc: 0.9762 - val
Epoch 115/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0805 - acc: 0.9754 - val
Epoch 116/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0831 - acc: 0.9751 - val
Epoch 117/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0787 - acc: 0.9769 - val
Epoch 118/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0873 - acc: 0.9754 - val
Epoch 119/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0814 - acc: 0.9770 - val
Epoch 120/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.0758 - acc: 0.9772 - val
Epoch 121/200
50000/50000 [==============================] - 3s 68us/step - loss: 0.0790 - acc: 0.9782 - val
Epoch 122/200
50000/50000 [==============================] - 3s 66us/step - loss: 0.0764 - acc: 0.9765 - val
Epoch 123/200
50000/50000 [==============================] - 4s 73us/step - loss: 0.0724 - acc: 0.9783 - val
Epoch 124/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.0853 - acc: 0.9762 - val
Epoch 125/200
50000/50000 [==============================] - 4s 73us/step - loss: 0.0809 - acc: 0.9763 - val
Epoch 126/200
50000/50000 [==============================] - 4s 71us/step - loss: 0.0741 - acc: 0.9793 - val
Epoch 127/200
50000/50000 [==============================] - 4s 71us/step - loss: 0.0775 - acc: 0.9771 - val
Epoch 128/200
50000/50000 [==============================] - 3s 70us/step - loss: 0.0728 - acc: 0.9775 - val
Epoch 129/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.0737 - acc: 0.9781 - val
Epoch 130/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0848 - acc: 0.9766 - val
Epoch 131/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0820 - acc: 0.9791 - val
Epoch 132/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0939 - acc: 0.9759 - val
Epoch 133/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0864 - acc: 0.9778 - val
Epoch 134/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0715 - acc: 0.9796 - val
Epoch 135/200
```

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50000/50000 [==============================] - 3s 61us/step - loss: 0.0762 - acc: 0.9780 - val
Epoch 136/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0687 - acc: 0.9801 - val
Epoch 137/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0783 - acc: 0.9792 - val
Epoch 138/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0785 - acc: 0.9790 - val
Epoch 139/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0818 - acc: 0.9787 - val
Epoch 140/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0861 - acc: 0.9778 - val
Epoch 141/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0823 - acc: 0.9791 - val
Epoch 142/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0754 - acc: 0.9789 - val
Epoch 143/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0660 - acc: 0.9807 - val
Epoch 144/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0712 - acc: 0.9800 - val
Epoch 145/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0688 - acc: 0.9807 - val
Epoch 146/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0683 - acc: 0.9803 - val
Epoch 147/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0833 - acc: 0.9790 - val
Epoch 148/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0623 - acc: 0.9806 - val
Epoch 149/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0686 - acc: 0.9807 - val
Epoch 150/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0834 - acc: 0.9799 - val
Epoch 151/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0744 - acc: 0.9805 - val
Epoch 152/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0734 - acc: 0.9813 - val
Epoch 153/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0704 - acc: 0.9815 - val
Epoch 154/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0821 - acc: 0.9795 - val
Epoch 155/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0668 - acc: 0.9823 - val
Epoch 156/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0629 - acc: 0.9828 - val
Epoch 157/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0676 - acc: 0.9827 - val
Epoch 158/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0652 - acc: 0.9832 - val
Epoch 159/200
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50000/50000 [==============================] - 3s 61us/step - loss: 0.0743 - acc: 0.9808 - val
Epoch 160/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0728 - acc: 0.9812 - val
Epoch 161/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0780 - acc: 0.9804 - val
Epoch 162/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0722 - acc: 0.9798 - val
Epoch 163/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0776 - acc: 0.9813 - val
Epoch 164/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0673 - acc: 0.9823 - val
Epoch 165/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0695 - acc: 0.9818 - val
Epoch 166/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0701 - acc: 0.9814 - val
Epoch 167/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0606 - acc: 0.9835 - val
Epoch 168/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0776 - acc: 0.9816 - val
Epoch 169/200
50000/50000 [==============================] - 3s 63us/step - loss: 0.0684 - acc: 0.9830 - val
Epoch 170/200
50000/50000 [==============================] - 3s 60us/step - loss: 0.0668 - acc: 0.9823 - val
Epoch 171/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0659 - acc: 0.9827 - val
Epoch 172/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0571 - acc: 0.9836 - val
Epoch 173/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0610 - acc: 0.9837 - val
Epoch 174/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0668 - acc: 0.9819 - val
Epoch 175/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0557 - acc: 0.9848 - val
Epoch 176/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0666 - acc: 0.9825 - val
Epoch 177/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0651 - acc: 0.9828 - val
Epoch 178/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0623 - acc: 0.9835 - val
Epoch 179/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.0837 - acc: 0.9817 - val
Epoch 180/200
50000/50000 [==============================] - 3s 67us/step - loss: 0.0724 - acc: 0.9834 - val
Epoch 181/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0595 - acc: 0.9846 - val
Epoch 182/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0634 - acc: 0.9842 - val
Epoch 183/200
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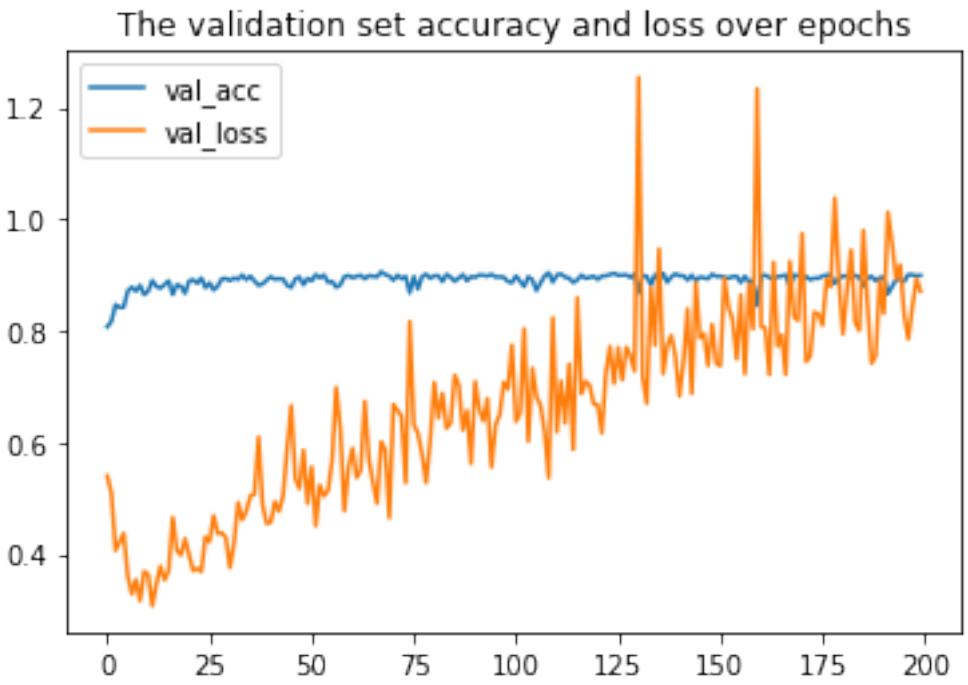
50000/50000 [==============================] - 3s 64us/step - loss: 0.0670 - acc: 0.9832 - val
Epoch 184/200
50000/50000 [==============================] - 3s 65us/step - loss: 0.0751 - acc: 0.9826 - val
Epoch 185/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0603 - acc: 0.9843 - val
Epoch 186/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0613 - acc: 0.9841 - val
Epoch 187/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0976 - acc: 0.9806 - val
Epoch 188/200
50000/50000 [==============================] - 3s 64us/step - loss: 0.0645 - acc: 0.9853 - val
Epoch 189/200
50000/50000 [==============================] - 3s 63us/step - loss: 0.0631 - acc: 0.9836 - val
Epoch 190/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0584 - acc: 0.9841 - val
Epoch 191/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0581 - acc: 0.9851 - val
Epoch 192/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0546 - acc: 0.9847 - val
Epoch 193/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0642 - acc: 0.9831 - val
Epoch 194/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0736 - acc: 0.9838 - val
Epoch 195/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0673 - acc: 0.9840 - val
Epoch 196/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0606 - acc: 0.9841 - val
Epoch 197/200
50000/50000 [==============================] - 3s 62us/step - loss: 0.0650 - acc: 0.9841 - val
Epoch 198/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0816 - acc: 0.9834 - val
Epoch 199/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0648 - acc: 0.9856 - val
Epoch 200/200
50000/50000 [==============================] - 3s 61us/step - loss: 0.0624 - acc: 0.9859 - val
```

```
In [31]: import matplotlib.pyplot as plt
```

```
In [32]: val_acc = result.history['val_acc']
         val_loss = result.history['val_loss']
         plt.plot(val_acc)
         plt.plot(val_loss)
         plt.legend(['val_acc', 'val_loss'])
         plt.title('The validation set accuracy and loss over epochs')
         plt.show()
```



From above plot we can see that the validation set accuracy remains the same over the epochs while the loss grows larger over the epochs. It suggests that the model performs worse along the epochs based on the validation dataset.

ii

```
In [34]: network_dropout = models.Sequential()
         network_dropout.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_dropout.add(layers.Dropout(0.5))
         network_dropout.add(layers.Dense(512, activation='relu'))
         network_dropout.add(layers.Dropout(0.5))
         network_dropout.add(layers.Dense(512, activation='relu'))
         network_dropout.add(layers.Dropout(0.5))
         network_dropout.add(layers.Dense(512, activation='relu'))
         network_dropout.add(layers.Dropout(0.5))
         network_dropout.add(layers.Dense(10, activation='softmax'))
         network_dropout.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=
         result_dropout = network_dropout.fit(x_train, y_train, validation_data=(x_valid, y_val

Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.9804 - acc: 0.6346 - val_
Epoch 2/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.5922 - acc: 0.7839 - val_
Epoch 3/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.5146 - acc: 0.8160 - val_
Epoch 4/200
```

```
50000/50000 [==============================] - 4s 78us/step - loss: 0.4809 - acc: 0.8292 - val
Epoch 5/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.4517 - acc: 0.8409 - val
Epoch 6/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.4278 - acc: 0.8477 - val
Epoch 7/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.4255 - acc: 0.8506 - val
Epoch 8/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.4010 - acc: 0.8588 - val
Epoch 9/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3974 - acc: 0.8597 - val
Epoch 10/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3824 - acc: 0.8646 - val
Epoch 11/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3818 - acc: 0.8663 - val
Epoch 12/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3707 - acc: 0.8701 - val
Epoch 13/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3648 - acc: 0.8711 - val
Epoch 14/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3547 - acc: 0.8764 - val
Epoch 15/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3492 - acc: 0.8755 - val
Epoch 16/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3525 - acc: 0.8765 - val
Epoch 17/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3467 - acc: 0.8773 - val
Epoch 18/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3402 - acc: 0.8795 - val
Epoch 19/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3390 - acc: 0.8818 - val
Epoch 20/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3344 - acc: 0.8823 - val
Epoch 21/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3346 - acc: 0.8823 - val
Epoch 22/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3334 - acc: 0.8838 - val
Epoch 23/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3256 - acc: 0.8852 - val
Epoch 24/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3214 - acc: 0.8875 - val
Epoch 25/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3192 - acc: 0.8891 - val
Epoch 26/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3214 - acc: 0.8873 - val
Epoch 27/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3208 - acc: 0.8899 - val
Epoch 28/200
```

```
50000/50000 [==============================] - 4s 80us/step - loss: 0.3198 - acc: 0.8896 - val
Epoch 29/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3157 - acc: 0.8905 - val
Epoch 30/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3145 - acc: 0.8892 - val
Epoch 31/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3118 - acc: 0.8924 - val
Epoch 32/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3137 - acc: 0.8907 - val
Epoch 33/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3091 - acc: 0.8936 - val
Epoch 34/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3080 - acc: 0.8923 - val
Epoch 35/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3098 - acc: 0.8936 - val
Epoch 36/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3080 - acc: 0.8938 - val
Epoch 37/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3048 - acc: 0.8947 - val
Epoch 38/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2988 - acc: 0.8952 - val
Epoch 39/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3026 - acc: 0.8954 - val
Epoch 40/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3070 - acc: 0.8946 - val
Epoch 41/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.3009 - acc: 0.8977 - val
Epoch 42/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2999 - acc: 0.8980 - val
Epoch 43/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3028 - acc: 0.8969 - val
Epoch 44/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2979 - acc: 0.8973 - val
Epoch 45/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2939 - acc: 0.8983 - val
Epoch 46/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2963 - acc: 0.8980 - val
Epoch 47/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2978 - acc: 0.8989 - val
Epoch 48/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2964 - acc: 0.8983 - val
Epoch 49/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2976 - acc: 0.8969 - val
Epoch 50/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.2932 - acc: 0.8988 - val
Epoch 51/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.2918 - acc: 0.9012 - val
Epoch 52/200
```

```
50000/50000 [==============================] - 4s 82us/step - loss: 0.2897 - acc: 0.9002 - val
Epoch 53/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2901 - acc: 0.9014 - val
Epoch 54/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2967 - acc: 0.9011 - val
Epoch 55/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.2966 - acc: 0.9016 - val
Epoch 56/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2908 - acc: 0.8994 - val
Epoch 57/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2939 - acc: 0.9012 - val
Epoch 58/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2933 - acc: 0.9015 - val
Epoch 59/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2909 - acc: 0.9022 - val
Epoch 60/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2918 - acc: 0.9027 - val
Epoch 61/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2903 - acc: 0.9028 - val
Epoch 62/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2912 - acc: 0.9023 - val
Epoch 63/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2899 - acc: 0.9031 - val
Epoch 64/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2914 - acc: 0.9027 - val
Epoch 65/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2825 - acc: 0.9036 - val
Epoch 66/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2957 - acc: 0.9028 - val
Epoch 67/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2945 - acc: 0.9041 - val
Epoch 68/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2891 - acc: 0.9054 - val
Epoch 69/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2974 - acc: 0.9033 - val
Epoch 70/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2946 - acc: 0.9032 - val
Epoch 71/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2916 - acc: 0.9034 - val
Epoch 72/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2857 - acc: 0.9049 - val
Epoch 73/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2886 - acc: 0.9059 - val
Epoch 74/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2923 - acc: 0.9041 - val
Epoch 75/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2980 - acc: 0.9034 - val
Epoch 76/200
```

```
50000/50000 [==============================] - 4s 80us/step - loss: 0.2902 - acc: 0.9049 - val
Epoch 77/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2887 - acc: 0.9056 - val
Epoch 78/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2954 - acc: 0.9055 - val
Epoch 79/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2951 - acc: 0.9030 - val
Epoch 80/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2930 - acc: 0.9061 - val
Epoch 81/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.2949 - acc: 0.9052 - val
Epoch 82/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2903 - acc: 0.9073 - val
Epoch 83/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2943 - acc: 0.9059 - val
Epoch 84/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2938 - acc: 0.9057 - val
Epoch 85/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2999 - acc: 0.9050 - val
Epoch 86/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2903 - acc: 0.9060 - val
Epoch 87/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2982 - acc: 0.9061 - val
Epoch 88/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.2950 - acc: 0.9082 - val
Epoch 89/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2967 - acc: 0.9069 - val
Epoch 90/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2954 - acc: 0.9069 - val
Epoch 91/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2925 - acc: 0.9081 - val
Epoch 92/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2985 - acc: 0.9059 - val
Epoch 93/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3043 - acc: 0.9063 - val
Epoch 94/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2938 - acc: 0.9087 - val
Epoch 95/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2970 - acc: 0.9080 - val
Epoch 96/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3035 - acc: 0.9061 - val
Epoch 97/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3011 - acc: 0.9068 - val
Epoch 98/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2953 - acc: 0.9068 - val
Epoch 99/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2920 - acc: 0.9074 - val
Epoch 100/200
```

```
50000/50000 [==============================] - 4s 80us/step - loss: 0.2959 - acc: 0.9091 - val
Epoch 101/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3043 - acc: 0.9077 - val
Epoch 102/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.2903 - acc: 0.9101 - val
Epoch 103/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.2885 - acc: 0.9089 - val
Epoch 104/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3011 - acc: 0.9082 - val
Epoch 105/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2998 - acc: 0.9091 - val
Epoch 106/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2932 - acc: 0.9098 - val
Epoch 107/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2973 - acc: 0.9101 - val
Epoch 108/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2940 - acc: 0.9099 - val
Epoch 109/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3069 - acc: 0.9077 - val
Epoch 110/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3019 - acc: 0.9089 - val
Epoch 111/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3055 - acc: 0.9101 - val
Epoch 112/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3052 - acc: 0.9093 - val
Epoch 113/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3030 - acc: 0.9080 - val
Epoch 114/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.2996 - acc: 0.9104 - val
Epoch 115/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3026 - acc: 0.9098 - val
Epoch 116/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3058 - acc: 0.9096 - val
Epoch 117/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3040 - acc: 0.9106 - val
Epoch 118/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3118 - acc: 0.9089 - val
Epoch 119/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3149 - acc: 0.9090 - val
Epoch 120/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3054 - acc: 0.9092 - val
Epoch 121/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3083 - acc: 0.9125 - val
Epoch 122/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3099 - acc: 0.9096 - val
Epoch 123/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3068 - acc: 0.9116 - val
Epoch 124/200
```

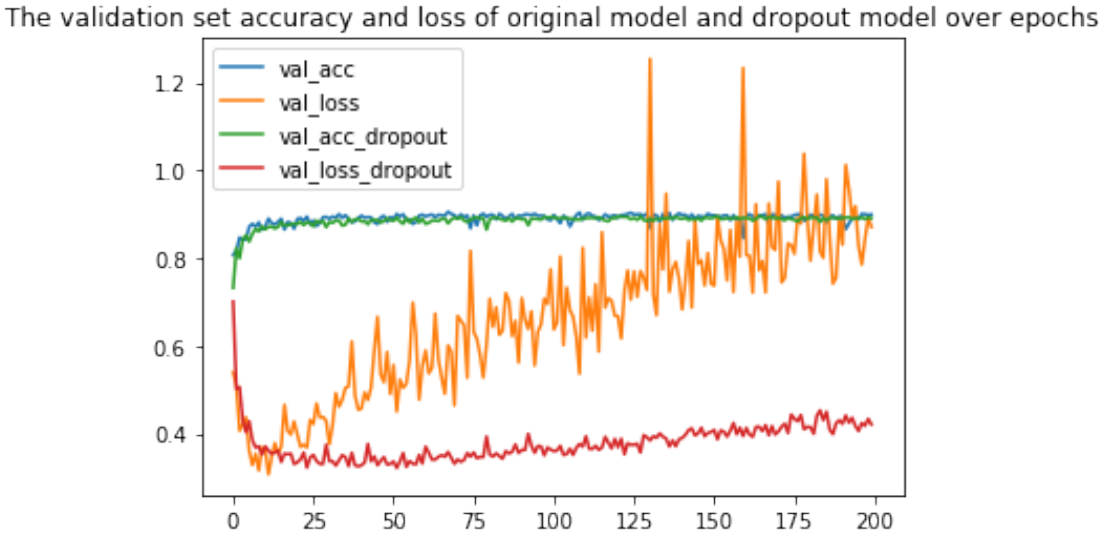
```
50000/50000 [==============================] - 4s 78us/step - loss: 0.3036 - acc: 0.9114 - val
Epoch 125/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3154 - acc: 0.9097 - val
Epoch 126/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3058 - acc: 0.9106 - val
Epoch 127/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3130 - acc: 0.9098 - val
Epoch 128/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3220 - acc: 0.9084 - val
Epoch 129/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3192 - acc: 0.9105 - val
Epoch 130/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3365 - acc: 0.9082 - val
Epoch 131/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3152 - acc: 0.9095 - val
Epoch 132/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3003 - acc: 0.9115 - val
Epoch 133/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3257 - acc: 0.9094 - val
Epoch 134/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3173 - acc: 0.9100 - val
Epoch 135/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3280 - acc: 0.9093 - val
Epoch 136/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3232 - acc: 0.9099 - val
Epoch 137/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3118 - acc: 0.9095 - val
Epoch 138/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3064 - acc: 0.9133 - val
Epoch 139/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3210 - acc: 0.9099 - val
Epoch 140/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3273 - acc: 0.9102 - val
Epoch 141/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3276 - acc: 0.9107 - val
Epoch 142/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3074 - acc: 0.9113 - val
Epoch 143/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3501 - acc: 0.9086 - val
Epoch 144/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3272 - acc: 0.9103 - val
Epoch 145/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3238 - acc: 0.9106 - val
Epoch 146/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3336 - acc: 0.9083 - val
Epoch 147/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3167 - acc: 0.9116 - val
Epoch 148/200
```

```
50000/50000 [==============================] - 4s 78us/step - loss: 0.3238 - acc: 0.9111 - val
Epoch 149/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3264 - acc: 0.9103 - val
Epoch 150/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3303 - acc: 0.9114 - val
Epoch 151/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3244 - acc: 0.9128 - val
Epoch 152/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3296 - acc: 0.9113 - val
Epoch 153/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3375 - acc: 0.9098 - val
Epoch 154/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3361 - acc: 0.9111 - val
Epoch 155/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3455 - acc: 0.9089 - val
Epoch 156/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3209 - acc: 0.9125 - val
Epoch 157/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3268 - acc: 0.9112 - val
Epoch 158/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3329 - acc: 0.9119 - val
Epoch 159/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3348 - acc: 0.9125 - val
Epoch 160/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3246 - acc: 0.9110 - val
Epoch 161/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3250 - acc: 0.9105 - val
Epoch 162/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3173 - acc: 0.9145 - val
Epoch 163/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3372 - acc: 0.9108 - val
Epoch 164/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3372 - acc: 0.9107 - val
Epoch 165/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3378 - acc: 0.9121 - val
Epoch 166/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3452 - acc: 0.9126 - val
Epoch 167/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3363 - acc: 0.9116 - val
Epoch 168/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3493 - acc: 0.9104 - val
Epoch 169/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3372 - acc: 0.9103 - val
Epoch 170/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3394 - acc: 0.9109 - val
Epoch 171/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3289 - acc: 0.9111 - val
Epoch 172/200
```

```
50000/50000 [==============================] - 4s 81us/step - loss: 0.3362 - acc: 0.9093 - val
Epoch 173/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3316 - acc: 0.9121 - val
Epoch 174/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.3314 - acc: 0.9137 - val
Epoch 175/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.3462 - acc: 0.9121 - val
Epoch 176/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3503 - acc: 0.9101 - val
Epoch 177/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3520 - acc: 0.9119 - val
Epoch 178/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3540 - acc: 0.9094 - val
Epoch 179/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3651 - acc: 0.9104 - val
Epoch 180/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3699 - acc: 0.9098 - val
Epoch 181/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3511 - acc: 0.9117 - val
Epoch 182/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3563 - acc: 0.9107 - val
Epoch 183/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.3424 - acc: 0.9122 - val
Epoch 184/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.3525 - acc: 0.9128 - val
Epoch 185/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.3733 - acc: 0.9111 - val
Epoch 186/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.3433 - acc: 0.9134 - val
Epoch 187/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3693 - acc: 0.9110 - val
Epoch 188/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3545 - acc: 0.9113 - val
Epoch 189/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.3524 - acc: 0.9106 - val
Epoch 190/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3506 - acc: 0.9096 - val
Epoch 191/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.3671 - acc: 0.9111 - val
Epoch 192/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.3719 - acc: 0.9117 - val
Epoch 193/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3638 - acc: 0.9124 - val
Epoch 194/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3769 - acc: 0.9119 - val
Epoch 195/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3494 - acc: 0.9113 - val
Epoch 196/200
```

```
50000/50000 [==============================] - 4s 80us/step - loss: 0.3490 - acc: 0.9135 - val
Epoch 197/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3526 - acc: 0.9118 - val
Epoch 198/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3607 - acc: 0.9117 - val
Epoch 199/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3545 - acc: 0.9122 - val
Epoch 200/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.3752 - acc: 0.9081 - val
```

```
In [35]: val_acc = result.history['val_acc']
         val_loss = result.history['val_loss']
         val_acc_dropout = result_dropout.history['val_acc']
         val_loss_dropout = result_dropout.history['val_loss']
         plt.plot(val_acc)
         plt.plot(val_loss)
         plt.plot(val_acc_dropout)
         plt.plot(val_loss_dropout)
         plt.legend(['val_acc', 'val_loss', 'val_acc_dropout', 'val_loss_dropout'])
         plt.title('The validation set accuracy and loss of original model and dropout model o
         plt.show()
```



Comparing to the first model, the second model is much better with lower validity loss, but the validity accuracy are similar between the two models.

iii. Weight regularization

```
In [37]: from keras import regularizers
```

```
In [39]: network_L1 = models.Sequential()
         network_L1.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel_reg
```

```
network_L1.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l
network_L1.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l
network_L1.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l
network_L1.add(layers.Dense(10, activation='softmax'))
network_L1.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['ac
result_L1 = network_L1.fit(x_train, y_train, validation_data=(x_valid, y_valid), epoc
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 4s 83us/step - loss: 14.7979 - acc: 0.5434 - val
Epoch 2/200
50000/50000 [==============================] - 4s 70us/step - loss: 3.0904 - acc: 0.6505 - val_
Epoch 3/200
50000/50000 [==============================] - 3s 70us/step - loss: 2.2152 - acc: 0.6997 - val_
Epoch 4/200
50000/50000 [==============================] - 4s 70us/step - loss: 1.9088 - acc: 0.7312 - val_
Epoch 5/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.7697 - acc: 0.7483 - val_
Epoch 6/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.6712 - acc: 0.7648 - val_
Epoch 7/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.6019 - acc: 0.7724 - val_
Epoch 8/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.5483 - acc: 0.7784 - val_
Epoch 9/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.5108 - acc: 0.7861 - val_
Epoch 10/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.4856 - acc: 0.7882 - val_
Epoch 11/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.4658 - acc: 0.7937 - val_
Epoch 12/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.4387 - acc: 0.7962 - val_
Epoch 13/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.4204 - acc: 0.7995 - val_
Epoch 14/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.4051 - acc: 0.8022 - val_
Epoch 15/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3884 - acc: 0.8057 - val_
Epoch 16/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.3733 - acc: 0.8073 - val_
Epoch 17/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3640 - acc: 0.8086 - val_
Epoch 18/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.3532 - acc: 0.8106 - val_
Epoch 19/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3440 - acc: 0.8132 - val_
Epoch 20/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3346 - acc: 0.8137 - val_
```

```
Epoch 21/200
50000/50000 [==============================] - 4s 74us/step - loss: 1.3259 - acc: 0.8151 - val
Epoch 22/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3174 - acc: 0.8176 - val
Epoch 23/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.3128 - acc: 0.8174 - val
Epoch 24/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.3036 - acc: 0.8196 - val
Epoch 25/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2973 - acc: 0.8209 - val
Epoch 26/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2905 - acc: 0.8223 - val
Epoch 27/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2893 - acc: 0.8206 - val
Epoch 28/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2846 - acc: 0.8212 - val
Epoch 29/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2792 - acc: 0.8238 - val
Epoch 30/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2786 - acc: 0.8227 - val
Epoch 31/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2730 - acc: 0.8266 - val
Epoch 32/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2713 - acc: 0.8256 - val
Epoch 33/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2707 - acc: 0.8249 - val
Epoch 34/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2668 - acc: 0.8251 - val
Epoch 35/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2632 - acc: 0.8258 - val
Epoch 36/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2599 - acc: 0.8273 - val
Epoch 37/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2591 - acc: 0.8266 - val
Epoch 38/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2501 - acc: 0.8299 - val
Epoch 39/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2534 - acc: 0.8292 - val
Epoch 40/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2501 - acc: 0.8299 - val
Epoch 41/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2473 - acc: 0.8302 - val
Epoch 42/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2435 - acc: 0.8289 - val
Epoch 43/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2400 - acc: 0.8317 - val
Epoch 44/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2400 - acc: 0.8311 - val
```

```
Epoch 45/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2356 - acc: 0.8313 - val
Epoch 46/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2370 - acc: 0.8316 - val
Epoch 47/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2317 - acc: 0.8327 - val
Epoch 48/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2319 - acc: 0.8336 - val
Epoch 49/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2300 - acc: 0.8331 - val
Epoch 50/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2308 - acc: 0.8334 - val
Epoch 51/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2261 - acc: 0.8344 - val
Epoch 52/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2258 - acc: 0.8342 - val
Epoch 53/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2269 - acc: 0.8338 - val
Epoch 54/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2223 - acc: 0.8343 - val
Epoch 55/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2224 - acc: 0.8348 - val
Epoch 56/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2164 - acc: 0.8377 - val
Epoch 57/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.2183 - acc: 0.8342 - val
Epoch 58/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.2132 - acc: 0.8374 - val
Epoch 59/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2176 - acc: 0.8358 - val
Epoch 60/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2137 - acc: 0.8368 - val
Epoch 61/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2139 - acc: 0.8359 - val
Epoch 62/200
50000/50000 [==============================] - 4s 70us/step - loss: 1.2133 - acc: 0.8360 - val
Epoch 63/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2111 - acc: 0.8381 - val
Epoch 64/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2067 - acc: 0.8379 - val
Epoch 65/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2090 - acc: 0.8370 - val
Epoch 66/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2075 - acc: 0.8381 - val
Epoch 67/200
50000/50000 [==============================] - 4s 70us/step - loss: 1.2104 - acc: 0.8373 - val
Epoch 68/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2071 - acc: 0.8372 - val
```

```
Epoch 69/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2064 - acc: 0.8380 - val
Epoch 70/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2037 - acc: 0.8387 - val
Epoch 71/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2016 - acc: 0.8382 - val
Epoch 72/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2049 - acc: 0.8374 - val
Epoch 73/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2000 - acc: 0.8394 - val
Epoch 74/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.2012 - acc: 0.8381 - val
Epoch 75/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1996 - acc: 0.8392 - val
Epoch 76/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1987 - acc: 0.8393 - val
Epoch 77/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1964 - acc: 0.8413 - val
Epoch 78/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1979 - acc: 0.8387 - val
Epoch 79/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1951 - acc: 0.8397 - val
Epoch 80/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1959 - acc: 0.8393 - val
Epoch 81/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1941 - acc: 0.8395 - val
Epoch 82/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1949 - acc: 0.8409 - val
Epoch 83/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1933 - acc: 0.8396 - val
Epoch 84/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1932 - acc: 0.8404 - val
Epoch 85/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1917 - acc: 0.8417 - val
Epoch 86/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1905 - acc: 0.8431 - val
Epoch 87/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1898 - acc: 0.8406 - val
Epoch 88/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1926 - acc: 0.8406 - val
Epoch 89/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1868 - acc: 0.8419 - val
Epoch 90/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1852 - acc: 0.8431 - val
Epoch 91/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1870 - acc: 0.8418 - val
Epoch 92/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1858 - acc: 0.8419 - val
```

```
Epoch 93/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1846 - acc: 0.8430 - val
Epoch 94/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1813 - acc: 0.8431 - val
Epoch 95/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1853 - acc: 0.8423 - val
Epoch 96/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1831 - acc: 0.8413 - val
Epoch 97/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1854 - acc: 0.8413 - val
Epoch 98/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1811 - acc: 0.8438 - val
Epoch 99/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1812 - acc: 0.8408 - val
Epoch 100/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1817 - acc: 0.8418 - val
Epoch 101/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1743 - acc: 0.8453 - val
Epoch 102/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1819 - acc: 0.8420 - val
Epoch 103/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1794 - acc: 0.8419 - val
Epoch 104/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1747 - acc: 0.8459 - val
Epoch 105/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1774 - acc: 0.8434 - val
Epoch 106/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1752 - acc: 0.8454 - val
Epoch 107/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1781 - acc: 0.8438 - val
Epoch 108/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1743 - acc: 0.8441 - val
Epoch 109/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1755 - acc: 0.8433 - val
Epoch 110/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1784 - acc: 0.8429 - val
Epoch 111/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1752 - acc: 0.8426 - val
Epoch 112/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1735 - acc: 0.8440 - val
Epoch 113/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1729 - acc: 0.8439 - val
Epoch 114/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1728 - acc: 0.8436 - val
Epoch 115/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1722 - acc: 0.8449 - val
Epoch 116/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1729 - acc: 0.8443 - val
```

```
Epoch 117/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1714 - acc: 0.8443 - val
Epoch 118/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1717 - acc: 0.8450 - val
Epoch 119/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1712 - acc: 0.8445 - val
Epoch 120/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1713 - acc: 0.8443 - val
Epoch 121/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1712 - acc: 0.8447 - val
Epoch 122/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1688 - acc: 0.8462 - val
Epoch 123/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1691 - acc: 0.8450 - val
Epoch 124/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1686 - acc: 0.8461 - val
Epoch 125/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1667 - acc: 0.8459 - val
Epoch 126/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1687 - acc: 0.8449 - val
Epoch 127/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1700 - acc: 0.8427 - val
Epoch 128/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1674 - acc: 0.8448 - val
Epoch 129/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1698 - acc: 0.8439 - val
Epoch 130/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1668 - acc: 0.8452 - val
Epoch 131/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1641 - acc: 0.8468 - val
Epoch 132/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1671 - acc: 0.8445 - val
Epoch 133/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1650 - acc: 0.8447 - val
Epoch 134/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1691 - acc: 0.8447 - val
Epoch 135/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1635 - acc: 0.8491 - val
Epoch 136/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1646 - acc: 0.8466 - val
Epoch 137/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1661 - acc: 0.8454 - val
Epoch 138/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1664 - acc: 0.8468 - val
Epoch 139/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1643 - acc: 0.8451 - val
Epoch 140/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1634 - acc: 0.8475 - val
```

```
Epoch 141/200
50000/50000 [==============================] - 4s 74us/step - loss: 1.1644 - acc: 0.8451 - val
Epoch 142/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1616 - acc: 0.8467 - val
Epoch 143/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1618 - acc: 0.8467 - val
Epoch 144/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1597 - acc: 0.8466 - val
Epoch 145/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1634 - acc: 0.8474 - val
Epoch 146/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1601 - acc: 0.8476 - val
Epoch 147/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1599 - acc: 0.8473 - val
Epoch 148/200
50000/50000 [==============================] - 4s 74us/step - loss: 1.1639 - acc: 0.8476 - val
Epoch 149/200
50000/50000 [==============================] - 4s 80us/step - loss: 1.1594 - acc: 0.8464 - val
Epoch 150/200
50000/50000 [==============================] - 4s 83us/step - loss: 1.1610 - acc: 0.8465 - val
Epoch 151/200
50000/50000 [==============================] - 4s 82us/step - loss: 1.1612 - acc: 0.8463 - val
Epoch 152/200
50000/50000 [==============================] - 4s 78us/step - loss: 1.1589 - acc: 0.8481 - val
Epoch 153/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1575 - acc: 0.8473 - val
Epoch 154/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1603 - acc: 0.8477 - val
Epoch 155/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1580 - acc: 0.8479 - val
Epoch 156/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1594 - acc: 0.8465 - val
Epoch 157/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1576 - acc: 0.8469 - val
Epoch 158/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1584 - acc: 0.8474 - val
Epoch 159/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1586 - acc: 0.8458 - val
Epoch 160/200
50000/50000 [==============================] - 4s 81us/step - loss: 1.1579 - acc: 0.8472 - val
Epoch 161/200
50000/50000 [==============================] - 4s 74us/step - loss: 1.1571 - acc: 0.8486 - val
Epoch 162/200
50000/50000 [==============================] - 4s 75us/step - loss: 1.1568 - acc: 0.8488 - val
Epoch 163/200
50000/50000 [==============================] - 4s 79us/step - loss: 1.1586 - acc: 0.8472 - val
Epoch 164/200
50000/50000 [==============================] - 4s 80us/step - loss: 1.1555 - acc: 0.8474 - val
```

```
Epoch 165/200
50000/50000 [==============================] - 4s 82us/step - loss: 1.1591 - acc: 0.8459 - val
Epoch 166/200
50000/50000 [==============================] - 4s 79us/step - loss: 1.1585 - acc: 0.8463 - val
Epoch 167/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1543 - acc: 0.8478 - val
Epoch 168/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1598 - acc: 0.8458 - val
Epoch 169/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1559 - acc: 0.8472 - val
Epoch 170/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1565 - acc: 0.8470 - val
Epoch 171/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1554 - acc: 0.8469 - val
Epoch 172/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1558 - acc: 0.8479 - val
Epoch 173/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1545 - acc: 0.8484 - val
Epoch 174/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1552 - acc: 0.8476 - val
Epoch 175/200
50000/50000 [==============================] - 3s 70us/step - loss: 1.1528 - acc: 0.8489 - val
Epoch 176/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1561 - acc: 0.8458 - val
Epoch 177/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1542 - acc: 0.8473 - val
Epoch 178/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1555 - acc: 0.8456 - val
Epoch 179/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1534 - acc: 0.8486 - val
Epoch 180/200
50000/50000 [==============================] - 3s 69us/step - loss: 1.1525 - acc: 0.8483 - val
Epoch 181/200
50000/50000 [==============================] - 4s 70us/step - loss: 1.1507 - acc: 0.8494 - val
Epoch 182/200
50000/50000 [==============================] - 4s 73us/step - loss: 1.1523 - acc: 0.8487 - val
Epoch 183/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1566 - acc: 0.8476 - val
Epoch 184/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1484 - acc: 0.8499 - val
Epoch 185/200
50000/50000 [==============================] - 4s 71us/step - loss: 1.1520 - acc: 0.8494 - val
Epoch 186/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1518 - acc: 0.8486 - val
Epoch 187/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1533 - acc: 0.8475 - val
Epoch 188/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1522 - acc: 0.8488 - val
```

```
Epoch 189/200
50000/50000 [==============================] - 4s 72us/step - loss: 1.1509 - acc: 0.8495 - val
Epoch 190/200
50000/50000 [==============================] - 4s 74us/step - loss: 1.1500 - acc: 0.8501 - val
Epoch 191/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1495 - acc: 0.8493 - val
Epoch 192/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1482 - acc: 0.8489 - val
Epoch 193/200
50000/50000 [==============================] - 4s 75us/step - loss: 1.1511 - acc: 0.8497 - val
Epoch 194/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1496 - acc: 0.8489 - val
Epoch 195/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1481 - acc: 0.8494 - val
Epoch 196/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1505 - acc: 0.8488 - val
Epoch 197/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1503 - acc: 0.8492 - val
Epoch 198/200
50000/50000 [==============================] - 4s 77us/step - loss: 1.1493 - acc: 0.8490 - val
Epoch 199/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1501 - acc: 0.8488 - val
Epoch 200/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1477 - acc: 0.8496 - val
```

```
In [40]: network_L2 = models.Sequential()
         network_L2.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel_reg
         network_L2.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l2
         network_L2.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l2
         network_L2.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l2
         network_L2.add(layers.Dense(10, activation='softmax'))
         network_L2.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['acc
         result_L2 = network_L2.fit(x_train, y_train, validation_data=(x_valid, y_valid), epoch
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 5s 92us/step - loss: 2.1615 - acc: 0.6706 - val
Epoch 2/200
50000/50000 [==============================] - 4s 76us/step - loss: 1.1934 - acc: 0.7875 - val
Epoch 3/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.8948 - acc: 0.8105 - val
Epoch 4/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.7519 - acc: 0.8269 - val
Epoch 5/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.6734 - acc: 0.8348 - val
Epoch 6/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.6131 - acc: 0.8436 - val
```

```
Epoch 7/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.5846 - acc: 0.8455 - val
Epoch 8/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.5551 - acc: 0.8524 - val
Epoch 9/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.5350 - acc: 0.8572 - val
Epoch 10/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.5175 - acc: 0.8611 - val
Epoch 11/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.5045 - acc: 0.8615 - val
Epoch 12/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4941 - acc: 0.8654 - val
Epoch 13/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4835 - acc: 0.8649 - val
Epoch 14/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4774 - acc: 0.8675 - val
Epoch 15/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4678 - acc: 0.8711 - val
Epoch 16/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4580 - acc: 0.8739 - val
Epoch 17/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4549 - acc: 0.8736 - val
Epoch 18/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4488 - acc: 0.8749 - val
Epoch 19/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4451 - acc: 0.8756 - val
Epoch 20/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4411 - acc: 0.8765 - val
Epoch 21/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4328 - acc: 0.8783 - val
Epoch 22/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4276 - acc: 0.8805 - val
Epoch 23/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.4276 - acc: 0.8804 - val
Epoch 24/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.4200 - acc: 0.8834 - val
Epoch 25/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.4171 - acc: 0.8845 - val
Epoch 26/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.4133 - acc: 0.8845 - val
Epoch 27/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.4085 - acc: 0.8865 - va
Epoch 28/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.4086 - acc: 0.8852 - val
Epoch 29/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.4060 - acc: 0.8862 - val
Epoch 30/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.4020 - acc: 0.8882 - val
```

```
Epoch 31/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3997 - acc: 0.8890 - val
Epoch 32/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3981 - acc: 0.8898 - val
Epoch 33/200
50000/50000 [==============================] - 4s 75us/step - loss: 0.3957 - acc: 0.8898 - val
Epoch 34/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3955 - acc: 0.8896 - val
Epoch 35/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3904 - acc: 0.8906 - val
Epoch 36/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3887 - acc: 0.8928 - val
Epoch 37/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3891 - acc: 0.8918 - val
Epoch 38/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3865 - acc: 0.8930 - val
Epoch 39/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3878 - acc: 0.8926 - val
Epoch 40/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3806 - acc: 0.8951 - val
Epoch 41/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3809 - acc: 0.8940 - val
Epoch 42/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3787 - acc: 0.8944 - val
Epoch 43/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3788 - acc: 0.8959 - val
Epoch 44/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3758 - acc: 0.8960 - val
Epoch 45/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3766 - acc: 0.8969 - val
Epoch 46/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3741 - acc: 0.8961 - val
Epoch 47/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3696 - acc: 0.8982 - val
Epoch 48/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3684 - acc: 0.8989 - val
Epoch 49/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3710 - acc: 0.8966 - val
Epoch 50/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3700 - acc: 0.8973 - val
Epoch 51/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3672 - acc: 0.8978 - val
Epoch 52/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3701 - acc: 0.8982 - val
Epoch 53/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3635 - acc: 0.8988 - val
Epoch 54/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3617 - acc: 0.9000 - val
```

```
Epoch 55/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3627 - acc: 0.9004 - val
Epoch 56/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3648 - acc: 0.8987 - val
Epoch 57/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3562 - acc: 0.9012 - val
Epoch 58/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3581 - acc: 0.9014 - val
Epoch 59/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3563 - acc: 0.9015 - val
Epoch 60/200
50000/50000 [==============================] - 4s 75us/step - loss: 0.3585 - acc: 0.9002 - val
Epoch 61/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3554 - acc: 0.9034 - val
Epoch 62/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3554 - acc: 0.9037 - val
Epoch 63/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3578 - acc: 0.9013 - val
Epoch 64/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3507 - acc: 0.9041 - val
Epoch 65/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3579 - acc: 0.9026 - val
Epoch 66/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3469 - acc: 0.9047 - val
Epoch 67/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3527 - acc: 0.9035 - val
Epoch 68/200
50000/50000 [==============================] - 4s 75us/step - loss: 0.3519 - acc: 0.9028 - val
Epoch 69/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3514 - acc: 0.9031 - val
Epoch 70/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3502 - acc: 0.9037 - val
Epoch 71/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.3493 - acc: 0.9046 - val
Epoch 72/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.3495 - acc: 0.9049 - val
Epoch 73/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.3478 - acc: 0.9057 - val
Epoch 74/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3466 - acc: 0.9052 - val
Epoch 75/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3466 - acc: 0.9065 - val
Epoch 76/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3451 - acc: 0.9060 - val
Epoch 77/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3453 - acc: 0.9063 - val
Epoch 78/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3464 - acc: 0.9044 - val
```

```
Epoch 79/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3471 - acc: 0.9039 - val
Epoch 80/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3432 - acc: 0.9075 - val
Epoch 81/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3447 - acc: 0.9060 - val
Epoch 82/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3454 - acc: 0.9066 - val
Epoch 83/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3435 - acc: 0.9068 - val
Epoch 84/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3446 - acc: 0.9069 - val
Epoch 85/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3407 - acc: 0.9086 - val
Epoch 86/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3436 - acc: 0.9073 - val
Epoch 87/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3403 - acc: 0.9084 - val
Epoch 88/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3435 - acc: 0.9069 - val
Epoch 89/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3371 - acc: 0.9087 - val
Epoch 90/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3393 - acc: 0.9080 - val
Epoch 91/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3418 - acc: 0.9081 - val
Epoch 92/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3399 - acc: 0.9092 - val
Epoch 93/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3410 - acc: 0.9071 - val
Epoch 94/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3344 - acc: 0.9114 - val
Epoch 95/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3388 - acc: 0.9077 - val
Epoch 96/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3390 - acc: 0.9093 - val
Epoch 97/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3379 - acc: 0.9086 - val
Epoch 98/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3365 - acc: 0.9105 - val
Epoch 99/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3372 - acc: 0.9097 - val
Epoch 100/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3340 - acc: 0.9100 - val
Epoch 101/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3350 - acc: 0.9108 - val
Epoch 102/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3361 - acc: 0.9085 - val
```

```
Epoch 103/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3327 - acc: 0.9106 - val
Epoch 104/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3357 - acc: 0.9108 - val
Epoch 105/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3348 - acc: 0.9119 - val
Epoch 106/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3351 - acc: 0.9098 - val
Epoch 107/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3332 - acc: 0.9103 - val
Epoch 108/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3351 - acc: 0.9108 - val
Epoch 109/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3313 - acc: 0.9124 - val
Epoch 110/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3307 - acc: 0.9115 - val
Epoch 111/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3305 - acc: 0.9129 - val
Epoch 112/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.3318 - acc: 0.9120 - val
Epoch 113/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.3299 - acc: 0.9123 - val
Epoch 114/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3297 - acc: 0.9117 - val
Epoch 115/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3315 - acc: 0.9105 - val
Epoch 116/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3315 - acc: 0.9114 - val
Epoch 117/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3324 - acc: 0.9112 - val
Epoch 118/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3315 - acc: 0.9138 - val
Epoch 119/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3302 - acc: 0.9122 - val
Epoch 120/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3300 - acc: 0.9124 - val
Epoch 121/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3285 - acc: 0.9133 - val
Epoch 122/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3283 - acc: 0.9138 - val
Epoch 123/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3247 - acc: 0.9158 - val
Epoch 124/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3279 - acc: 0.9133 - val
Epoch 125/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3273 - acc: 0.9136 - val
Epoch 126/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3271 - acc: 0.9138 - val
```

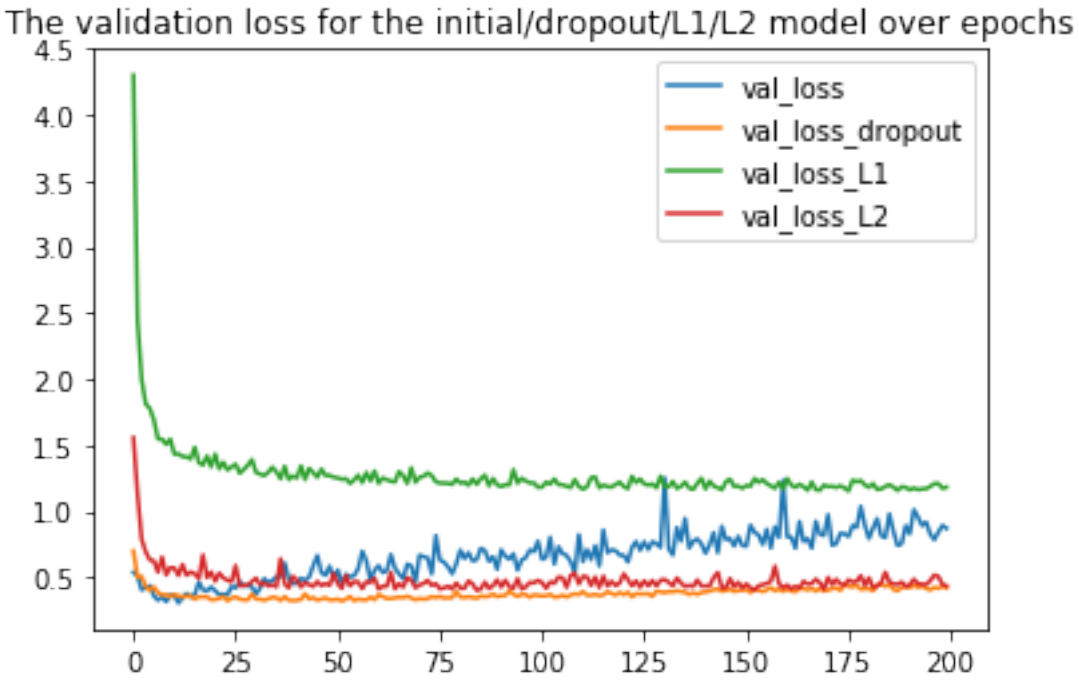
```
Epoch 127/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3253 - acc: 0.9137 - val
Epoch 128/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3263 - acc: 0.9130 - val
Epoch 129/200
50000/50000 [==============================] - 4s 83us/step - loss: 0.3244 - acc: 0.9133 - val
Epoch 130/200
50000/50000 [==============================] - 4s 90us/step - loss: 0.3291 - acc: 0.9129 - val
Epoch 131/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.3266 - acc: 0.9115 - val
Epoch 132/200
50000/50000 [==============================] - 4s 82us/step - loss: 0.3250 - acc: 0.9158 - val
Epoch 133/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3266 - acc: 0.9134 - val
Epoch 134/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3256 - acc: 0.9145 - val
Epoch 135/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3252 - acc: 0.9129 - val
Epoch 136/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3245 - acc: 0.9154 - val
Epoch 137/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3259 - acc: 0.9137 - val
Epoch 138/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3229 - acc: 0.9147 - val
Epoch 139/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3233 - acc: 0.9160 - val
Epoch 140/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3225 - acc: 0.9154 - val
Epoch 141/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3244 - acc: 0.9144 - val
Epoch 142/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3238 - acc: 0.9158 - val
Epoch 143/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3203 - acc: 0.9152 - val
Epoch 144/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3251 - acc: 0.9147 - val
Epoch 145/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3226 - acc: 0.9157 - val
Epoch 146/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3246 - acc: 0.9137 - val
Epoch 147/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3226 - acc: 0.9153 - val
Epoch 148/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3253 - acc: 0.9146 - val
Epoch 149/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3219 - acc: 0.9157 - val
Epoch 150/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3257 - acc: 0.9145 - val
```

```
Epoch 151/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3178 - acc: 0.9177 - val
Epoch 152/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3199 - acc: 0.9171 - val
Epoch 153/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3219 - acc: 0.9165 - val
Epoch 154/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3216 - acc: 0.9170 - val
Epoch 155/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3198 - acc: 0.9169 - val
Epoch 156/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3182 - acc: 0.9183 - val
Epoch 157/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3198 - acc: 0.9173 - val
Epoch 158/200
50000/50000 [==============================] - 4s 77us/step - loss: 0.3196 - acc: 0.9158 - val
Epoch 159/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3192 - acc: 0.9183 - val
Epoch 160/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3193 - acc: 0.9177 - val
Epoch 161/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3222 - acc: 0.9155 - val
Epoch 162/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3195 - acc: 0.9174 - val
Epoch 163/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3174 - acc: 0.9171 - val
Epoch 164/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3192 - acc: 0.9172 - val
Epoch 165/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3178 - acc: 0.9167 - val
Epoch 166/200
50000/50000 [==============================] - 4s 79us/step - loss: 0.3235 - acc: 0.9145 - val
Epoch 167/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3177 - acc: 0.9179 - val
Epoch 168/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3166 - acc: 0.9171 - val
Epoch 169/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3226 - acc: 0.9158 - val
Epoch 170/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3179 - acc: 0.9171 - val
Epoch 171/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3200 - acc: 0.9159 - val
Epoch 172/200
50000/50000 [==============================] - 4s 78us/step - loss: 0.3176 - acc: 0.9167 - val
Epoch 173/200
50000/50000 [==============================] - 4s 80us/step - loss: 0.3171 - acc: 0.9170 - val
Epoch 174/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.3154 - acc: 0.9174 - val
```

```
Epoch 175/200
50000/50000 [==============================] - 4s 84us/step - loss: 0.3168 - acc: 0.9180 - val
Epoch 176/200
50000/50000 [==============================] - 4s 90us/step - loss: 0.3168 - acc: 0.9176 - val
Epoch 177/200
50000/50000 [==============================] - 4s 90us/step - loss: 0.3160 - acc: 0.9183 - val
Epoch 178/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3193 - acc: 0.9181 - val
Epoch 179/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3171 - acc: 0.9180 - val
Epoch 180/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3147 - acc: 0.9198 - val
Epoch 181/200
50000/50000 [==============================] - 4s 81us/step - loss: 0.3215 - acc: 0.9163 - val
Epoch 182/200
50000/50000 [==============================] - 4s 71us/step - loss: 0.3120 - acc: 0.9190 - val
Epoch 183/200
50000/50000 [==============================] - 4s 71us/step - loss: 0.3143 - acc: 0.9182 - val
Epoch 184/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3169 - acc: 0.9180 - val
Epoch 185/200
50000/50000 [==============================] - 4s 72us/step - loss: 0.3130 - acc: 0.9193 - val
Epoch 186/200
50000/50000 [==============================] - 4s 72us/step - loss: 0.3126 - acc: 0.9183 - val
Epoch 187/200
50000/50000 [==============================] - 4s 72us/step - loss: 0.3153 - acc: 0.9178 - val
Epoch 188/200
50000/50000 [==============================] - 4s 73us/step - loss: 0.3147 - acc: 0.9179 - val
Epoch 189/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3151 - acc: 0.9186 - val
Epoch 190/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3139 - acc: 0.9189 - val
Epoch 191/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3144 - acc: 0.9168 - val
Epoch 192/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3145 - acc: 0.9184 - val
Epoch 193/200
50000/50000 [==============================] - 4s 76us/step - loss: 0.3157 - acc: 0.9176 - val
Epoch 194/200
50000/50000 [==============================] - 4s 75us/step - loss: 0.3153 - acc: 0.9177 - val
Epoch 195/200
50000/50000 [==============================] - 4s 75us/step - loss: 0.3163 - acc: 0.9191 - val
Epoch 196/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3136 - acc: 0.9185 - val
Epoch 197/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3102 - acc: 0.9189 - val
Epoch 198/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3115 - acc: 0.9196 - val
```

```
Epoch 199/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3145 - acc: 0.9168 - val
Epoch 200/200
50000/50000 [==============================] - 4s 74us/step - loss: 0.3147 - acc: 0.9177 - val
```

```
In [43]: val_loss = result.history['val_loss']
         val_loss_dropout = result_dropout.history['val_loss']
         val_loss_L1 = result_L1.history['val_loss']
         val_loss_L2 = result_L2.history['val_loss']
         plt.plot(val_loss)
         plt.plot(val_loss_dropout)
         plt.plot(val_loss_L1)
         plt.plot(val_loss_L2)
         plt.legend(['val_loss', 'val_loss_dropout', 'val_loss_L1', 'val_loss_L2'])
         plt.title('The validation loss for the initial/dropout/L1/L2 model over epochs')
         plt.show()
```



From above plot we can see that, when epoch smaller than 150, the dropout model performs the best. When epoch larger than 150, the L2 model performs the best.

iv.alternative models

```
In [45]: network_alt = models.Sequential()
         network_alt.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt.add(layers.Dropout(0.5))
         network_alt.add(layers.Dense(512, activation='relu'))
```

```
        network_alt.add(layers.Dropout(0.5))
        network_alt.add(layers.Dense(512, activation='relu'))
        network_alt.add(layers.Dropout(0.5))
        network_alt.add(layers.Dense(10, activation='softmax'))
        network_alt.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

        result_alt = network_alt.fit(x_train, y_train, validation_data=(x_valid, y_valid), epo
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 4s 75us/step - loss: 0.8610 - acc: 0.6833 - val
Epoch 2/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.5533 - acc: 0.8001 - val
Epoch 3/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.4889 - acc: 0.8226 - val
Epoch 4/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.4503 - acc: 0.8380 - val
Epoch 5/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.4261 - acc: 0.8462 - val
Epoch 6/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.4095 - acc: 0.8524 - val
Epoch 7/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.3912 - acc: 0.8596 - val
Epoch 8/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3815 - acc: 0.8611 - val
Epoch 9/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3629 - acc: 0.8679 - val
Epoch 10/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3614 - acc: 0.8700 - val
Epoch 11/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3566 - acc: 0.8701 - val
Epoch 12/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3462 - acc: 0.8739 - val
Epoch 13/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3430 - acc: 0.8761 - val
Epoch 14/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3378 - acc: 0.8763 - val
Epoch 15/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3324 - acc: 0.8797 - val
Epoch 16/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3263 - acc: 0.8835 - val
Epoch 17/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3233 - acc: 0.8830 - val
Epoch 18/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3183 - acc: 0.8843 - val
Epoch 19/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3181 - acc: 0.8839 - val
Epoch 20/100
```

```
50000/50000 [==============================] - 3s 61us/step - loss: 0.3130 - acc: 0.8862 - val
Epoch 21/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3089 - acc: 0.8880 - val
Epoch 22/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3084 - acc: 0.8890 - val
Epoch 23/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3042 - acc: 0.8902 - val
Epoch 24/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3002 - acc: 0.8917 - val
Epoch 25/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.3007 - acc: 0.8918 - val
Epoch 26/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.2934 - acc: 0.8926 - val
Epoch 27/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.2975 - acc: 0.8930 - val
Epoch 28/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2904 - acc: 0.8945 - val
Epoch 29/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2917 - acc: 0.8948 - val
Epoch 30/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2924 - acc: 0.8931 - val
Epoch 31/100
50000/50000 [==============================] - 3s 70us/step - loss: 0.2899 - acc: 0.8955 - val
Epoch 32/100
50000/50000 [==============================] - 4s 72us/step - loss: 0.2822 - acc: 0.8973 - val
Epoch 33/100
50000/50000 [==============================] - 4s 74us/step - loss: 0.2827 - acc: 0.8983 - val
Epoch 34/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2814 - acc: 0.8981 - val
Epoch 35/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2807 - acc: 0.8997 - val
Epoch 36/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2760 - acc: 0.8997 - val
Epoch 37/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2756 - acc: 0.8990 - val
Epoch 38/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2753 - acc: 0.9010 - val
Epoch 39/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2747 - acc: 0.9023 - val
Epoch 40/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2706 - acc: 0.9023 - val
Epoch 41/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2655 - acc: 0.9024 - val
Epoch 42/100
50000/50000 [==============================] - 4s 71us/step - loss: 0.2677 - acc: 0.9049 - val
Epoch 43/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2686 - acc: 0.9032 - val
Epoch 44/100
```

```
50000/50000 [==============================] - 3s 62us/step - loss: 0.2686 - acc: 0.9033 - val
Epoch 45/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.2643 - acc: 0.9051 - val
Epoch 46/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2622 - acc: 0.9056 - val
Epoch 47/100
50000/50000 [==============================] - 3s 69us/step - loss: 0.2604 - acc: 0.9070 - val
Epoch 48/100
50000/50000 [==============================] - 3s 68us/step - loss: 0.2582 - acc: 0.9072 - val
Epoch 49/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2577 - acc: 0.9084 - val
Epoch 50/100
50000/50000 [==============================] - 3s 66us/step - loss: 0.2602 - acc: 0.9056 - val
Epoch 51/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2532 - acc: 0.9068 - val
Epoch 52/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2572 - acc: 0.9074 - val
Epoch 53/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2551 - acc: 0.9089 - val
Epoch 54/100
50000/50000 [==============================] - 3s 68us/step - loss: 0.2556 - acc: 0.9078 - val
Epoch 55/100
50000/50000 [==============================] - 3s 66us/step - loss: 0.2511 - acc: 0.9099 - val
Epoch 56/100
50000/50000 [==============================] - 3s 66us/step - loss: 0.2498 - acc: 0.9107 - val
Epoch 57/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2510 - acc: 0.9103 - val
Epoch 58/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2475 - acc: 0.9114 - val
Epoch 59/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2448 - acc: 0.9123 - val
Epoch 60/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2462 - acc: 0.9122 - val
Epoch 61/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2465 - acc: 0.9118 - val
Epoch 62/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2439 - acc: 0.9130 - val
Epoch 63/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2382 - acc: 0.9145 - val
Epoch 64/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2411 - acc: 0.9117 - val
Epoch 65/100
50000/50000 [==============================] - 3s 68us/step - loss: 0.2423 - acc: 0.9135 - val
Epoch 66/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2423 - acc: 0.9142 - val
Epoch 67/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2384 - acc: 0.9132 - val
Epoch 68/100
```

```
50000/50000 [==============================] - 3s 65us/step - loss: 0.2407 - acc: 0.9145 - val
Epoch 69/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2399 - acc: 0.9160 - val
Epoch 70/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2343 - acc: 0.9162 - val
Epoch 71/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2369 - acc: 0.9170 - val
Epoch 72/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2368 - acc: 0.9171 - val
Epoch 73/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2367 - acc: 0.9169 - val
Epoch 74/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2371 - acc: 0.9151 - val
Epoch 75/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2340 - acc: 0.9179 - val
Epoch 76/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2339 - acc: 0.9179 - val
Epoch 77/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2324 - acc: 0.9186 - val
Epoch 78/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2315 - acc: 0.9180 - val
Epoch 79/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2351 - acc: 0.9176 - val
Epoch 80/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2279 - acc: 0.9201 - val
Epoch 81/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2283 - acc: 0.9190 - val
Epoch 82/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2259 - acc: 0.9202 - val
Epoch 83/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2257 - acc: 0.9204 - val
Epoch 84/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2286 - acc: 0.9198 - val
Epoch 85/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2278 - acc: 0.9211 - val
Epoch 86/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2276 - acc: 0.9213 - val
Epoch 87/100
50000/50000 [==============================] - 3s 66us/step - loss: 0.2292 - acc: 0.9206 - val
Epoch 88/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2268 - acc: 0.9188 - val
Epoch 89/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.2249 - acc: 0.9221 - val
Epoch 90/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2224 - acc: 0.9221 - val
Epoch 91/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2258 - acc: 0.9205 - val
Epoch 92/100
```

```
50000/50000 [==============================] - 3s 64us/step - loss: 0.2221 - acc: 0.9236 - val
Epoch 93/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2210 - acc: 0.9231 - val
Epoch 94/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2227 - acc: 0.9229 - val
Epoch 95/100
50000/50000 [==============================] - 3s 65us/step - loss: 0.2224 - acc: 0.9229 - val
Epoch 96/100
50000/50000 [==============================] - 3s 64us/step - loss: 0.2168 - acc: 0.9238 - val
Epoch 97/100
50000/50000 [==============================] - 4s 70us/step - loss: 0.2207 - acc: 0.9224 - val
Epoch 98/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.2186 - acc: 0.9230 - val
Epoch 99/100
50000/50000 [==============================] - 3s 67us/step - loss: 0.2227 - acc: 0.9236 - val
Epoch 100/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.2227 - acc: 0.9228 - val
```

```
In [46]: network_alt2 = models.Sequential()
         network_alt2.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt2.add(layers.Dropout(0.5))
         network_alt2.add(layers.Dense(512, activation='relu'))
         network_alt2.add(layers.Dropout(0.5))
         network_alt2.add(layers.Dense(512, activation='relu'))
         network_alt2.add(layers.Dropout(0.5))
         network_alt2.add(layers.Dense(512, activation='relu'))
         network_alt2.add(layers.Dropout(0.5))
         network_alt2.add(layers.Dense(10, activation='softmax'))
         network_alt2.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

         result_alt2 = network_alt2.fit(x_train, y_train, validation_data=(x_valid, y_valid), e

Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 5s 98us/step - loss: 0.9831 - acc: 0.6319 - val
Epoch 2/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.5915 - acc: 0.7878 - val
Epoch 3/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.5173 - acc: 0.8168 - val
Epoch 4/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.4813 - acc: 0.8290 - val
Epoch 5/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.4480 - acc: 0.8405 - val
Epoch 6/100
50000/50000 [==============================] - 5s 105us/step - loss: 0.4264 - acc: 0.8471 - va
Epoch 7/100
50000/50000 [==============================] - 4s 89us/step - loss: 0.4122 - acc: 0.8539 - val
```

```
Epoch 8/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.4000 - acc: 0.8570 - val
Epoch 9/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.3908 - acc: 0.8608 - val
Epoch 10/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3816 - acc: 0.8643 - val
Epoch 11/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3771 - acc: 0.8662 - val
Epoch 12/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.3691 - acc: 0.8707 - val
Epoch 13/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3630 - acc: 0.8719 - val
Epoch 14/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3574 - acc: 0.8736 - val
Epoch 15/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3529 - acc: 0.8742 - val
Epoch 16/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.3511 - acc: 0.8770 - val
Epoch 17/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3492 - acc: 0.8770 - val
Epoch 18/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3411 - acc: 0.8789 - val
Epoch 19/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3409 - acc: 0.8796 - val
Epoch 20/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3376 - acc: 0.8823 - val
Epoch 21/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3362 - acc: 0.8820 - val
Epoch 22/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3323 - acc: 0.8831 - val
Epoch 23/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.3310 - acc: 0.8830 - val
Epoch 24/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3248 - acc: 0.8868 - val
Epoch 25/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3258 - acc: 0.8870 - val
Epoch 26/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3192 - acc: 0.8866 - val
Epoch 27/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3173 - acc: 0.8881 - val
Epoch 28/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3216 - acc: 0.8877 - val
Epoch 29/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3174 - acc: 0.8899 - val
Epoch 30/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3152 - acc: 0.8895 - val
Epoch 31/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3122 - acc: 0.8900 - val
```

```
Epoch 32/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3147 - acc: 0.8913 - val
Epoch 33/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3107 - acc: 0.8929 - val
Epoch 34/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.3109 - acc: 0.8915 - val
Epoch 35/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3068 - acc: 0.8929 - val
Epoch 36/100
50000/50000 [==============================] - 5s 90us/step - loss: 0.3104 - acc: 0.8920 - val
Epoch 37/100
50000/50000 [==============================] - 5s 108us/step - loss: 0.3128 - acc: 0.8915 - va
Epoch 38/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3053 - acc: 0.8945 - val
Epoch 39/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3022 - acc: 0.8946 - val
Epoch 40/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3028 - acc: 0.8959 - val
Epoch 41/100
50000/50000 [==============================] - 4s 87us/step - loss: 0.3039 - acc: 0.8962 - val
Epoch 42/100
50000/50000 [==============================] - 4s 87us/step - loss: 0.3064 - acc: 0.8958 - val
Epoch 43/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3019 - acc: 0.8961 - val
Epoch 44/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2987 - acc: 0.8971 - val
Epoch 45/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3008 - acc: 0.8965 - val
Epoch 46/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.2964 - acc: 0.8976 - val
Epoch 47/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3023 - acc: 0.8974 - val
Epoch 48/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2970 - acc: 0.8988 - val
Epoch 49/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2956 - acc: 0.8989 - val
Epoch 50/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2983 - acc: 0.8988 - val
Epoch 51/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2978 - acc: 0.8991 - val
Epoch 52/100
50000/50000 [==============================] - 4s 87us/step - loss: 0.3010 - acc: 0.8977 - val
Epoch 53/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2989 - acc: 0.8990 - val
Epoch 54/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3038 - acc: 0.8976 - val
Epoch 55/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.2941 - acc: 0.9012 - val
```

```
Epoch 56/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.2931 - acc: 0.9008 - val
Epoch 57/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.2949 - acc: 0.9001 - val
Epoch 58/100
50000/50000 [==============================] - 4s 87us/step - loss: 0.2943 - acc: 0.9015 - val
Epoch 59/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2964 - acc: 0.9018 - val
Epoch 60/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2943 - acc: 0.8989 - val
Epoch 61/100
50000/50000 [==============================] - 5s 97us/step - loss: 0.2964 - acc: 0.9017 - val
Epoch 62/100
50000/50000 [==============================] - 5s 100us/step - loss: 0.2924 - acc: 0.9023 - va
Epoch 63/100
50000/50000 [==============================] - 5s 93us/step - loss: 0.3009 - acc: 0.8998 - val
Epoch 64/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3008 - acc: 0.9020 - val
Epoch 65/100
50000/50000 [==============================] - 4s 88us/step - loss: 0.2999 - acc: 0.9006 - val
Epoch 66/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.2968 - acc: 0.9012 - val
Epoch 67/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.2969 - acc: 0.9003 - val
Epoch 68/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2963 - acc: 0.9015 - val
Epoch 69/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2951 - acc: 0.9032 - val
Epoch 70/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2925 - acc: 0.9046 - val
Epoch 71/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2982 - acc: 0.9008 - val
Epoch 72/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2949 - acc: 0.9036 - val
Epoch 73/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.2955 - acc: 0.9039 - val
Epoch 74/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2963 - acc: 0.9045 - val
Epoch 75/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2969 - acc: 0.9039 - val
Epoch 76/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.2964 - acc: 0.9038 - val
Epoch 77/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.2984 - acc: 0.9028 - val
Epoch 78/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2995 - acc: 0.9056 - val
Epoch 79/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2979 - acc: 0.9053 - val
```

```
Epoch 80/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.2980 - acc: 0.9047 - val
Epoch 81/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3022 - acc: 0.9041 - val
Epoch 82/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3019 - acc: 0.9040 - val
Epoch 83/100
50000/50000 [==============================] - 5s 97us/step - loss: 0.2948 - acc: 0.9064 - val
Epoch 84/100
50000/50000 [==============================] - 5s 95us/step - loss: 0.3003 - acc: 0.9045 - val
Epoch 85/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.2992 - acc: 0.9061 - val
Epoch 86/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.2996 - acc: 0.9067 - val
Epoch 87/100
50000/50000 [==============================] - 4s 85us/step - loss: 0.3008 - acc: 0.9048 - val
Epoch 88/100
50000/50000 [==============================] - 4s 86us/step - loss: 0.2965 - acc: 0.9059 - val
Epoch 89/100
50000/50000 [==============================] - 4s 87us/step - loss: 0.3125 - acc: 0.9054 - val
Epoch 90/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3028 - acc: 0.9049 - val
Epoch 91/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3026 - acc: 0.9073 - val
Epoch 92/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.3191 - acc: 0.9037 - val
Epoch 93/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3023 - acc: 0.9064 - val
Epoch 94/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2969 - acc: 0.9073 - val
Epoch 95/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3024 - acc: 0.9051 - val
Epoch 96/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.3016 - acc: 0.9061 - val
Epoch 97/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3080 - acc: 0.9055 - val
Epoch 98/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3129 - acc: 0.9051 - val
Epoch 99/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3007 - acc: 0.9077 - val
Epoch 100/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.3012 - acc: 0.9077 - val
```

```
In [47]: network_alt3 = models.Sequential()
         network_alt3.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt3.add(layers.Dropout(0.5))
         network_alt3.add(layers.Dense(512, activation='relu'))
```

```
network_alt3.add(layers.Dropout(0.5))
network_alt3.add(layers.Dense(10, activation='softmax'))
network_alt3.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

result_alt3 = network_alt3.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 3s 66us/step - loss: 0.7839 - acc: 0.7175 - val
Epoch 2/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.5185 - acc: 0.8118 - val
Epoch 3/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.4560 - acc: 0.8330 - val
Epoch 4/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.4221 - acc: 0.8457 - val
Epoch 5/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.3989 - acc: 0.8544 - val
Epoch 6/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.3856 - acc: 0.8581 - val
Epoch 7/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3689 - acc: 0.8660 - val
Epoch 8/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.3577 - acc: 0.8679 - val
Epoch 9/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3479 - acc: 0.8721 - val
Epoch 10/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3415 - acc: 0.8747 - val
Epoch 11/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3320 - acc: 0.8772 - val
Epoch 12/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3247 - acc: 0.8808 - val
Epoch 13/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3224 - acc: 0.8823 - val
Epoch 14/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3126 - acc: 0.8840 - val
Epoch 15/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3106 - acc: 0.8859 - val
Epoch 16/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.3027 - acc: 0.8874 - val
Epoch 17/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.3012 - acc: 0.8898 - val
Epoch 18/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2973 - acc: 0.8921 - val
Epoch 19/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2951 - acc: 0.8913 - val
Epoch 20/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2917 - acc: 0.8922 - val
Epoch 21/100
```

```
50000/50000 [==============================] - 2s 45us/step - loss: 0.2853 - acc: 0.8944 - val
Epoch 22/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2862 - acc: 0.8944 - val
Epoch 23/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2801 - acc: 0.8969 - val
Epoch 24/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.2759 - acc: 0.8977 - val
Epoch 25/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2754 - acc: 0.8980 - val
Epoch 26/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2724 - acc: 0.8992 - val
Epoch 27/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2690 - acc: 0.9008 - val
Epoch 28/100
50000/50000 [==============================] - 2s 47us/step - loss: 0.2670 - acc: 0.9016 - val
Epoch 29/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2643 - acc: 0.9031 - val
Epoch 30/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2625 - acc: 0.9031 - val
Epoch 31/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.2613 - acc: 0.9031 - val
Epoch 32/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2586 - acc: 0.9041 - val
Epoch 33/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2562 - acc: 0.9044 - val
Epoch 34/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.2558 - acc: 0.9057 - val
Epoch 35/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2522 - acc: 0.9079 - val
Epoch 36/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2502 - acc: 0.9065 - val
Epoch 37/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2519 - acc: 0.9061 - val
Epoch 38/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2471 - acc: 0.9083 - val
Epoch 39/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2451 - acc: 0.9092 - val
Epoch 40/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2464 - acc: 0.9096 - val
Epoch 41/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2428 - acc: 0.9115 - val
Epoch 42/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2405 - acc: 0.9104 - val
Epoch 43/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.2387 - acc: 0.9113 - val
Epoch 44/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.2389 - acc: 0.9117 - val
Epoch 45/100
```

```
50000/50000 [==============================] - 3s 54us/step - loss: 0.2369 - acc: 0.9144 - val
Epoch 46/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.2322 - acc: 0.9135 - val
Epoch 47/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2343 - acc: 0.9141 - val
Epoch 48/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.2309 - acc: 0.9154 - val
Epoch 49/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2316 - acc: 0.9158 - val
Epoch 50/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2307 - acc: 0.9145 - val
Epoch 51/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2248 - acc: 0.9169 - val
Epoch 52/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2261 - acc: 0.9173 - val
Epoch 53/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2273 - acc: 0.9176 - val
Epoch 54/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2255 - acc: 0.9167 - val
Epoch 55/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2231 - acc: 0.9194 - val
Epoch 56/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2246 - acc: 0.9169 - val
Epoch 57/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2225 - acc: 0.9186 - val
Epoch 58/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2179 - acc: 0.9199 - val
Epoch 59/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2211 - acc: 0.9186 - val
Epoch 60/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2166 - acc: 0.9195 - val
Epoch 61/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2185 - acc: 0.9195 - val
Epoch 62/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2177 - acc: 0.9216 - val
Epoch 63/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2155 - acc: 0.9216 - val
Epoch 64/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2175 - acc: 0.9210 - val
Epoch 65/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2112 - acc: 0.9222 - val
Epoch 66/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2148 - acc: 0.9219 - val
Epoch 67/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2105 - acc: 0.9227 - val
Epoch 68/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2110 - acc: 0.9234 - val
Epoch 69/100
```

```
50000/50000 [==============================] - 2s 43us/step - loss: 0.2106 - acc: 0.9225 - val
Epoch 70/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2071 - acc: 0.9243 - val
Epoch 71/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2079 - acc: 0.9242 - val
Epoch 72/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.2091 - acc: 0.9238 - val
Epoch 73/100
50000/50000 [==============================] - 3s 50us/step - loss: 0.2091 - acc: 0.9223 - val
Epoch 74/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.2056 - acc: 0.9248 - val
Epoch 75/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.2083 - acc: 0.9249 - val
Epoch 76/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.2050 - acc: 0.9253 - val
Epoch 77/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2063 - acc: 0.9248 - val
Epoch 78/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2060 - acc: 0.9263 - val
Epoch 79/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.2027 - acc: 0.9277 - val
Epoch 80/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2052 - acc: 0.9275 - val
Epoch 81/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1991 - acc: 0.9271 - val
Epoch 82/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1982 - acc: 0.9281 - val
Epoch 83/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1974 - acc: 0.9282 - val
Epoch 84/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.2003 - acc: 0.9269 - val
Epoch 85/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1968 - acc: 0.9259 - val
Epoch 86/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.1941 - acc: 0.9298 - val
Epoch 87/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.1940 - acc: 0.9293 - val
Epoch 88/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1935 - acc: 0.9290 - val
Epoch 89/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1976 - acc: 0.9286 - val
Epoch 90/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1969 - acc: 0.9289 - val
Epoch 91/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1901 - acc: 0.9303 - val
Epoch 92/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1942 - acc: 0.9295 - val
Epoch 93/100
```

```
50000/50000 [==============================] - 2s 44us/step - loss: 0.1895 - acc: 0.9320 - val
Epoch 94/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1873 - acc: 0.9314 - val
Epoch 95/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1937 - acc: 0.9283 - val
Epoch 96/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.1888 - acc: 0.9325 - val
Epoch 97/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1881 - acc: 0.9321 - val
Epoch 98/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1855 - acc: 0.9324 - val
Epoch 99/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1895 - acc: 0.9329 - val
Epoch 100/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.1879 - acc: 0.9316 - val
```

```
In [48]: network_alt4 = models.Sequential()
         network_alt4.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt4.add(layers.Dense(512, activation='relu'))
         network_alt4.add(layers.Dense(512, activation='relu'))
         network_alt4.add(layers.Dense(10, activation='softmax'))
         network_alt4.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

         result_alt4 = network_alt4.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 4s 72us/step - loss: 0.7921 - acc: 0.7097 - val
Epoch 2/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.4927 - acc: 0.8180 - val
Epoch 3/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.4164 - acc: 0.8446 - val
Epoch 4/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.3716 - acc: 0.8610 - val
Epoch 5/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.3411 - acc: 0.8717 - val
Epoch 6/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.3209 - acc: 0.8797 - val
Epoch 7/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.2995 - acc: 0.8872 - val
Epoch 8/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.2829 - acc: 0.8937 - val
Epoch 9/100
50000/50000 [==============================] - 3s 55us/step - loss: 0.2684 - acc: 0.8978 - val
Epoch 10/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.2613 - acc: 0.9007 - val
Epoch 11/100
```

```
50000/50000 [==============================] - 3s 56us/step - loss: 0.2461 - acc: 0.9054 - val
Epoch 12/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.2347 - acc: 0.9105 - val
Epoch 13/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.2273 - acc: 0.9134 - val
Epoch 14/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.2240 - acc: 0.9148 - val
Epoch 15/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.2095 - acc: 0.9201 - val
Epoch 16/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.2035 - acc: 0.9220 - val
Epoch 17/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.1947 - acc: 0.9265 - val
Epoch 18/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1906 - acc: 0.9270 - val
Epoch 19/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1823 - acc: 0.9304 - val
Epoch 20/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1747 - acc: 0.9322 - val
Epoch 21/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1708 - acc: 0.9336 - val
Epoch 22/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1655 - acc: 0.9350 - val
Epoch 23/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.1636 - acc: 0.9371 - val
Epoch 24/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.1578 - acc: 0.9392 - val
Epoch 25/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1494 - acc: 0.9426 - val
Epoch 26/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1466 - acc: 0.9435 - val
Epoch 27/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.1462 - acc: 0.9438 - val
Epoch 28/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.1370 - acc: 0.9461 - val
Epoch 29/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.1395 - acc: 0.9461 - val
Epoch 30/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.1308 - acc: 0.9491 - val
Epoch 31/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1302 - acc: 0.9502 - val
Epoch 32/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1260 - acc: 0.9509 - val
Epoch 33/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.1217 - acc: 0.9532 - val
Epoch 34/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1235 - acc: 0.9531 - val
Epoch 35/100
```

```
50000/50000 [==============================] - 3s 54us/step - loss: 0.1142 - acc: 0.9565 - val
Epoch 36/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.1202 - acc: 0.9550 - val
Epoch 37/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1123 - acc: 0.9581 - val
Epoch 38/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1170 - acc: 0.9576 - val
Epoch 39/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1107 - acc: 0.9590 - val
Epoch 40/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.1119 - acc: 0.9587 - val
Epoch 41/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1061 - acc: 0.9598 - val
Epoch 42/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.1033 - acc: 0.9614 - val
Epoch 43/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.1090 - acc: 0.9600 - val
Epoch 44/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0971 - acc: 0.9642 - val
Epoch 45/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0957 - acc: 0.9647 - val
Epoch 46/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0956 - acc: 0.9637 - val
Epoch 47/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0979 - acc: 0.9651 - val
Epoch 48/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0951 - acc: 0.9655 - val
Epoch 49/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0952 - acc: 0.9654 - val
Epoch 50/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0911 - acc: 0.9660 - val
Epoch 51/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0888 - acc: 0.9681 - val
Epoch 52/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0936 - acc: 0.9668 - val
Epoch 53/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0860 - acc: 0.9682 - val
Epoch 54/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0891 - acc: 0.9664 - val
Epoch 55/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0919 - acc: 0.9677 - val
Epoch 56/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0779 - acc: 0.9721 - val
Epoch 57/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0848 - acc: 0.9695 - val
Epoch 58/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0785 - acc: 0.9712 - val
Epoch 59/100
```

```
50000/50000 [==============================] - 3s 52us/step - loss: 0.0825 - acc: 0.9706 - val
Epoch 60/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0842 - acc: 0.9705 - val
Epoch 61/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0831 - acc: 0.9708 - val
Epoch 62/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0812 - acc: 0.9719 - val
Epoch 63/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0765 - acc: 0.9733 - val
Epoch 64/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0760 - acc: 0.9730 - val
Epoch 65/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0757 - acc: 0.9741 - val
Epoch 66/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0775 - acc: 0.9739 - val
Epoch 67/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0752 - acc: 0.9732 - val
Epoch 68/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0773 - acc: 0.9742 - val
Epoch 69/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0759 - acc: 0.9738 - val
Epoch 70/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0739 - acc: 0.9748 - val
Epoch 71/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.0789 - acc: 0.9738 - val
Epoch 72/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0743 - acc: 0.9750 - val
Epoch 73/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0736 - acc: 0.9752 - val
Epoch 74/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0710 - acc: 0.9764 - val
Epoch 75/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0710 - acc: 0.9754 - val
Epoch 76/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0690 - acc: 0.9768 - val
Epoch 77/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0704 - acc: 0.9777 - val
Epoch 78/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0719 - acc: 0.9770 - val
Epoch 79/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0680 - acc: 0.9767 - val
Epoch 80/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0721 - acc: 0.9762 - val
Epoch 81/100
50000/50000 [==============================] - 3s 56us/step - loss: 0.0698 - acc: 0.9774 - val
Epoch 82/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0662 - acc: 0.9790 - val
Epoch 83/100
```

```
50000/50000 [==============================] - 3s 56us/step - loss: 0.0685 - acc: 0.9777 - val
Epoch 84/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0660 - acc: 0.9787 - val
Epoch 85/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0708 - acc: 0.9770 - val
Epoch 86/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0742 - acc: 0.9772 - val
Epoch 87/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0649 - acc: 0.9792 - val
Epoch 88/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0693 - acc: 0.9783 - val
Epoch 89/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0626 - acc: 0.9796 - val
Epoch 90/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0709 - acc: 0.9787 - val
Epoch 91/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0689 - acc: 0.9780 - val
Epoch 92/100
50000/50000 [==============================] - 3s 51us/step - loss: 0.0646 - acc: 0.9800 - val
Epoch 93/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0638 - acc: 0.9795 - val
Epoch 94/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0698 - acc: 0.9789 - val
Epoch 95/100
50000/50000 [==============================] - 3s 52us/step - loss: 0.0615 - acc: 0.9800 - val
Epoch 96/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.0606 - acc: 0.9797 - val
Epoch 97/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.0647 - acc: 0.9792 - val
Epoch 98/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0637 - acc: 0.9802 - val
Epoch 99/100
50000/50000 [==============================] - 3s 53us/step - loss: 0.0563 - acc: 0.9811 - val
Epoch 100/100
50000/50000 [==============================] - 3s 54us/step - loss: 0.0646 - acc: 0.9798 - val
```

```
In [49]: network_alt5 = models.Sequential()
         network_alt5.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt5.add(layers.Dense(512, activation='relu'))
         network_alt5.add(layers.Dense(10, activation='softmax'))
         network_alt5.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

         result_alt5 = network_alt5.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7377 - acc: 0.7400 - val
```

```
Epoch 2/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.4631 - acc: 0.8290 - val
Epoch 3/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.3993 - acc: 0.8532 - val
Epoch 4/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.3571 - acc: 0.8674 - val
Epoch 5/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.3340 - acc: 0.8740 - val
Epoch 6/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.3085 - acc: 0.8844 - val
Epoch 7/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.2908 - acc: 0.8912 - val
Epoch 8/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.2756 - acc: 0.8963 - val
Epoch 9/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.2625 - acc: 0.9009 - val
Epoch 10/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.2486 - acc: 0.9059 - val
Epoch 11/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.2422 - acc: 0.9082 - val
Epoch 12/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.2281 - acc: 0.9122 - val
Epoch 13/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.2190 - acc: 0.9167 - val
Epoch 14/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.2124 - acc: 0.9189 - val
Epoch 15/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.2018 - acc: 0.9225 - val
Epoch 16/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1934 - acc: 0.9259 - val
Epoch 17/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.1856 - acc: 0.9294 - val
Epoch 18/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1829 - acc: 0.9309 - val
Epoch 19/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1737 - acc: 0.9334 - val
Epoch 20/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1668 - acc: 0.9366 - val
Epoch 21/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1603 - acc: 0.9383 - val
Epoch 22/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1544 - acc: 0.9410 - val
Epoch 23/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.1508 - acc: 0.9423 - val
Epoch 24/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1449 - acc: 0.9441 - val
Epoch 25/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1423 - acc: 0.9446 - val
```

```
Epoch 26/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1355 - acc: 0.9478 - val
Epoch 27/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1345 - acc: 0.9490 - val
Epoch 28/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1268 - acc: 0.9505 - val
Epoch 29/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.1252 - acc: 0.9522 - val
Epoch 30/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.1220 - acc: 0.9542 - val
Epoch 31/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.1185 - acc: 0.9544 - val
Epoch 32/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1150 - acc: 0.9563 - val
Epoch 33/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1070 - acc: 0.9585 - val
Epoch 34/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1047 - acc: 0.9599 - val
Epoch 35/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1024 - acc: 0.9600 - val
Epoch 36/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.1013 - acc: 0.9613 - val
Epoch 37/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0978 - acc: 0.9622 - val
Epoch 38/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0983 - acc: 0.9622 - val
Epoch 39/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0952 - acc: 0.9649 - val
Epoch 40/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0927 - acc: 0.9656 - val
Epoch 41/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.0891 - acc: 0.9667 - val
Epoch 42/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0896 - acc: 0.9666 - val
Epoch 43/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0850 - acc: 0.9674 - val
Epoch 44/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0869 - acc: 0.9675 - val
Epoch 45/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0789 - acc: 0.9695 - val
Epoch 46/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0806 - acc: 0.9700 - val
Epoch 47/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0743 - acc: 0.9721 - val
Epoch 48/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0762 - acc: 0.9718 - val
Epoch 49/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0780 - acc: 0.9721 - val
```

```
Epoch 50/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0716 - acc: 0.9740 - val
Epoch 51/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0745 - acc: 0.9736 - val
Epoch 52/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0703 - acc: 0.9745 - val
Epoch 53/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0699 - acc: 0.9745 - val
Epoch 54/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0646 - acc: 0.9761 - val
Epoch 55/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0651 - acc: 0.9762 - val
Epoch 56/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0611 - acc: 0.9767 - val
Epoch 57/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0662 - acc: 0.9767 - val
Epoch 58/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0668 - acc: 0.9767 - val
Epoch 59/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0589 - acc: 0.9787 - val
Epoch 60/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0631 - acc: 0.9780 - val
Epoch 61/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0542 - acc: 0.9802 - val
Epoch 62/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0541 - acc: 0.9798 - val
Epoch 63/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0572 - acc: 0.9792 - val
Epoch 64/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0533 - acc: 0.9809 - val
Epoch 65/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0558 - acc: 0.9809 - val
Epoch 66/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0551 - acc: 0.9809 - val
Epoch 67/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0531 - acc: 0.9806 - val
Epoch 68/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0505 - acc: 0.9826 - val
Epoch 69/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0513 - acc: 0.9819 - val
Epoch 70/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0516 - acc: 0.9823 - val
Epoch 71/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0488 - acc: 0.9825 - val
Epoch 72/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0470 - acc: 0.9833 - val
Epoch 73/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0529 - acc: 0.9830 - val
```

```
Epoch 74/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0511 - acc: 0.9840 - val
Epoch 75/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0484 - acc: 0.9836 - val
Epoch 76/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0544 - acc: 0.9825 - val
Epoch 77/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0416 - acc: 0.9853 - val
Epoch 78/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0465 - acc: 0.9842 - val
Epoch 79/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0469 - acc: 0.9854 - val
Epoch 80/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0434 - acc: 0.9856 - val
Epoch 81/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.0430 - acc: 0.9845 - val
Epoch 82/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0436 - acc: 0.9856 - val
Epoch 83/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0438 - acc: 0.9852 - val
Epoch 84/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0398 - acc: 0.9872 - val
Epoch 85/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0417 - acc: 0.9864 - val
Epoch 86/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.0443 - acc: 0.9850 - val
Epoch 87/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0400 - acc: 0.9866 - val
Epoch 88/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0407 - acc: 0.9862 - val
Epoch 89/100
50000/50000 [==============================] - 2s 38us/step - loss: 0.0406 - acc: 0.9869 - val
Epoch 90/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0390 - acc: 0.9871 - val
Epoch 91/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0382 - acc: 0.9874 - val
Epoch 92/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.0442 - acc: 0.9873 - val
Epoch 93/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0457 - acc: 0.9860 - val
Epoch 94/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0372 - acc: 0.9881 - val
Epoch 95/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0420 - acc: 0.9872 - val
Epoch 96/100
50000/50000 [==============================] - 2s 41us/step - loss: 0.0329 - acc: 0.9895 - val
Epoch 97/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0368 - acc: 0.9878 - val
```

```
Epoch 98/100
50000/50000 [==============================] - 2s 40us/step - loss: 0.0447 - acc: 0.9871 - val
Epoch 99/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0376 - acc: 0.9882 - val
Epoch 100/100
50000/50000 [==============================] - 2s 39us/step - loss: 0.0369 - acc: 0.9882 - val
```

```
In [50]: network_alt6 = models.Sequential()
         network_alt6.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
         network_alt6.add(layers.Dense(512, activation='relu'))
         network_alt6.add(layers.Dense(512, activation='relu'))
         network_alt6.add(layers.Dense(512, activation='relu'))
         network_alt6.add(layers.Dense(512, activation='relu'))
         network_alt6.add(layers.Dense(10, activation='softmax'))
         network_alt6.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

         result_alt6 = network_alt6.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 5s 98us/step - loss: 0.9660 - acc: 0.6454 - val
Epoch 2/100
50000/50000 [==============================] - 4s 75us/step - loss: 0.5421 - acc: 0.7992 - val
Epoch 3/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.4618 - acc: 0.8280 - val
Epoch 4/100
50000/50000 [==============================] - 4s 75us/step - loss: 0.4123 - acc: 0.8482 - val
Epoch 5/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.3852 - acc: 0.8608 - val
Epoch 6/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.3471 - acc: 0.8707 - val
Epoch 7/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.3285 - acc: 0.8781 - val
Epoch 8/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.3095 - acc: 0.8840 - val
Epoch 9/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.2935 - acc: 0.8911 - val
Epoch 10/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.2901 - acc: 0.8921 - val
Epoch 11/100
50000/50000 [==============================] - 4s 88us/step - loss: 0.2758 - acc: 0.8972 - val
Epoch 12/100
50000/50000 [==============================] - 4s 89us/step - loss: 0.2574 - acc: 0.9031 - val
Epoch 13/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.2543 - acc: 0.9047 - val
Epoch 14/100
50000/50000 [==============================] - 4s 83us/step - loss: 0.2398 - acc: 0.9084 - val
```

```
Epoch 15/100
50000/50000 [==============================] - 4s 75us/step - loss: 0.2325 - acc: 0.9129 - val
Epoch 16/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.2282 - acc: 0.9138 - val
Epoch 17/100
50000/50000 [==============================] - 5s 93us/step - loss: 0.2235 - acc: 0.9163 - val
Epoch 18/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.2186 - acc: 0.9181 - val
Epoch 19/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.2143 - acc: 0.9196 - val
Epoch 20/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.2124 - acc: 0.9206 - val
Epoch 21/100
50000/50000 [==============================] - 4s 80us/step - loss: 0.2057 - acc: 0.9223 - val
Epoch 22/100
50000/50000 [==============================] - 4s 80us/step - loss: 0.1974 - acc: 0.9252 - val
Epoch 23/100
50000/50000 [==============================] - 4s 84us/step - loss: 0.1950 - acc: 0.9269 - val
Epoch 24/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1968 - acc: 0.9275 - val
Epoch 25/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1858 - acc: 0.9290 - val
Epoch 26/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1910 - acc: 0.9301 - val
Epoch 27/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1856 - acc: 0.9310 - val
Epoch 28/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1775 - acc: 0.9345 - val
Epoch 29/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1812 - acc: 0.9333 - val
Epoch 30/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1761 - acc: 0.9350 - val
Epoch 31/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1739 - acc: 0.9354 - val
Epoch 32/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1655 - acc: 0.9392 - val
Epoch 33/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1718 - acc: 0.9381 - val
Epoch 34/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1664 - acc: 0.9377 - val
Epoch 35/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1599 - acc: 0.9406 - val
Epoch 36/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1609 - acc: 0.9414 - val
Epoch 37/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1652 - acc: 0.9401 - val
Epoch 38/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1595 - acc: 0.9418 - val
```

```
Epoch 39/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1616 - acc: 0.9414 - val
Epoch 40/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1537 - acc: 0.9436 - val
Epoch 41/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1521 - acc: 0.9450 - val
Epoch 42/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1452 - acc: 0.9460 - val
Epoch 43/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1497 - acc: 0.9460 - val
Epoch 44/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1493 - acc: 0.9464 - val
Epoch 45/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1482 - acc: 0.9474 - val
Epoch 46/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1462 - acc: 0.9484 - val
Epoch 47/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1407 - acc: 0.9496 - val
Epoch 48/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1337 - acc: 0.9508 - val
Epoch 49/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.1437 - acc: 0.9499 - val
Epoch 50/100
50000/50000 [==============================] - 5s 90us/step - loss: 0.1364 - acc: 0.9519 - val
Epoch 51/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1379 - acc: 0.9514 - val
Epoch 52/100
50000/50000 [==============================] - 4s 82us/step - loss: 0.1354 - acc: 0.9514 - val
Epoch 53/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1349 - acc: 0.9526 - val
Epoch 54/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1430 - acc: 0.9514 - val
Epoch 55/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1355 - acc: 0.9540 - val
Epoch 56/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1358 - acc: 0.9537 - val
Epoch 57/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1296 - acc: 0.9554 - val
Epoch 58/100
50000/50000 [==============================] - 4s 79us/step - loss: 0.1262 - acc: 0.9562 - val
Epoch 59/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1344 - acc: 0.9543 - val
Epoch 60/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1361 - acc: 0.9538 - val
Epoch 61/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1362 - acc: 0.9561 - val
Epoch 62/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1227 - acc: 0.9574 - val
```

```
Epoch 63/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1190 - acc: 0.9581 - val
Epoch 64/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1266 - acc: 0.9571 - val
Epoch 65/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1182 - acc: 0.9593 - val
Epoch 66/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1239 - acc: 0.9577 - val
Epoch 67/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1095 - acc: 0.9616 - val
Epoch 68/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1281 - acc: 0.9600 - val
Epoch 69/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1129 - acc: 0.9611 - val
Epoch 70/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1126 - acc: 0.9607 - val
Epoch 71/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1097 - acc: 0.9605 - val
Epoch 72/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1164 - acc: 0.9619 - val
Epoch 73/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1204 - acc: 0.9612 - val
Epoch 74/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1179 - acc: 0.9618 - val
Epoch 75/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1146 - acc: 0.9622 - val
Epoch 76/100
50000/50000 [==============================] - 4s 76us/step - loss: 0.1003 - acc: 0.9654 - val
Epoch 77/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1084 - acc: 0.9641 - val
Epoch 78/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1055 - acc: 0.9640 - val
Epoch 79/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1018 - acc: 0.9654 - val
Epoch 80/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1050 - acc: 0.9654 - val
Epoch 81/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1068 - acc: 0.9660 - val
Epoch 82/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1061 - acc: 0.9658 - val
Epoch 83/100
50000/50000 [==============================] - 4s 81us/step - loss: 0.1117 - acc: 0.9650 - val
Epoch 84/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1025 - acc: 0.9661 - val
Epoch 85/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1062 - acc: 0.9668 - val
Epoch 86/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0987 - acc: 0.9673 - val
```

```
Epoch 87/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1035 - acc: 0.9669 - val
Epoch 88/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1080 - acc: 0.9674 - val
Epoch 89/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.0994 - acc: 0.9688 - val
Epoch 90/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1158 - acc: 0.9670 - val
Epoch 91/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0981 - acc: 0.9695 - val
Epoch 92/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0974 - acc: 0.9715 - val
Epoch 93/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1068 - acc: 0.9684 - val
Epoch 94/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1030 - acc: 0.9703 - val
Epoch 95/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0951 - acc: 0.9699 - val
Epoch 96/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0911 - acc: 0.9712 - val
Epoch 97/100
50000/50000 [==============================] - 4s 77us/step - loss: 0.1169 - acc: 0.9676 - val
Epoch 98/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.1035 - acc: 0.9708 - val
Epoch 99/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0973 - acc: 0.9720 - val
Epoch 100/100
50000/50000 [==============================] - 4s 78us/step - loss: 0.0916 - acc: 0.9712 - val
```

```
In [51]: network_alt7 = models.Sequential()
         network_alt7.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel_r
         network_alt7.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt7.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt7.add(layers.Dense(10, activation='softmax'))
         network_alt7.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a

         result_alt7 = network_alt7.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 4s 81us/step - loss: 12.0186 - acc: 0.6118 - val
Epoch 2/100
50000/50000 [==============================] - 3s 58us/step - loss: 2.6428 - acc: 0.6955 - val
Epoch 3/100
50000/50000 [==============================] - 3s 57us/step - loss: 1.8881 - acc: 0.7235 - val
Epoch 4/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.6558 - acc: 0.7485 - val
```

```
Epoch 5/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.5340 - acc: 0.7620 - val
Epoch 6/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.4555 - acc: 0.7741 - val
Epoch 7/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.4070 - acc: 0.7817 - val
Epoch 8/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.3690 - acc: 0.7871 - val
Epoch 9/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.3380 - acc: 0.7939 - val
Epoch 10/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.3045 - acc: 0.7986 - val
Epoch 11/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.2833 - acc: 0.8041 - val
Epoch 12/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.2607 - acc: 0.8068 - val
Epoch 13/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.2452 - acc: 0.8105 - val
Epoch 14/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.2344 - acc: 0.8109 - val
Epoch 15/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.2157 - acc: 0.8156 - val
Epoch 16/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.2013 - acc: 0.8168 - val
Epoch 17/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1857 - acc: 0.8209 - val
Epoch 18/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1761 - acc: 0.8230 - val
Epoch 19/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1629 - acc: 0.8255 - val
Epoch 20/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.1545 - acc: 0.8278 - val
Epoch 21/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1502 - acc: 0.8272 - val
Epoch 22/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1445 - acc: 0.8302 - val
Epoch 23/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1402 - acc: 0.8291 - val
Epoch 24/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1339 - acc: 0.8299 - val
Epoch 25/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1277 - acc: 0.8314 - val
Epoch 26/100
50000/50000 [==============================] - 3s 61us/step - loss: 1.1237 - acc: 0.8312 - val
Epoch 27/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.1204 - acc: 0.8326 - val
Epoch 28/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.1143 - acc: 0.8340 - val
```

```
Epoch 29/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.1100 - acc: 0.8355 - val
Epoch 30/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.1098 - acc: 0.8335 - val
Epoch 31/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.1024 - acc: 0.8359 - val
Epoch 32/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.1026 - acc: 0.8362 - val
Epoch 33/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0993 - acc: 0.8381 - val
Epoch 34/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0951 - acc: 0.8372 - val
Epoch 35/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0894 - acc: 0.8396 - val
Epoch 36/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0908 - acc: 0.8377 - val
Epoch 37/100
50000/50000 [==============================] - 3s 61us/step - loss: 1.0880 - acc: 0.8378 - val
Epoch 38/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0852 - acc: 0.8395 - val
Epoch 39/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0810 - acc: 0.8400 - val
Epoch 40/100
50000/50000 [==============================] - 3s 62us/step - loss: 1.0777 - acc: 0.8397 - val
Epoch 41/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0799 - acc: 0.8394 - val
Epoch 42/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0765 - acc: 0.8417 - val
Epoch 43/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0745 - acc: 0.8405 - val
Epoch 44/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0687 - acc: 0.8427 - val
Epoch 45/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0676 - acc: 0.8420 - val
Epoch 46/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0670 - acc: 0.8422 - val
Epoch 47/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0627 - acc: 0.8413 - val
Epoch 48/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0625 - acc: 0.8428 - val
Epoch 49/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0616 - acc: 0.8420 - val
Epoch 50/100
50000/50000 [==============================] - ETA: 0s - loss: 1.0594 - acc: 0.842 - 3s 60us/st
Epoch 51/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0580 - acc: 0.8432 - val
Epoch 52/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0556 - acc: 0.8430 - val
```

```
Epoch 53/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0545 - acc: 0.8426 - val
Epoch 54/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0538 - acc: 0.8446 - val
Epoch 55/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0511 - acc: 0.8444 - val
Epoch 56/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0497 - acc: 0.8451 - val
Epoch 57/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0500 - acc: 0.8449 - val
Epoch 58/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0475 - acc: 0.8444 - val
Epoch 59/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0488 - acc: 0.8431 - val
Epoch 60/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0473 - acc: 0.8460 - val
Epoch 61/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0465 - acc: 0.8448 - val
Epoch 62/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0434 - acc: 0.8451 - val
Epoch 63/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0427 - acc: 0.8468 - val
Epoch 64/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0442 - acc: 0.8460 - val
Epoch 65/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0421 - acc: 0.8458 - val
Epoch 66/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0419 - acc: 0.8459 - val
Epoch 67/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0394 - acc: 0.8454 - val
Epoch 68/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0387 - acc: 0.8466 - val
Epoch 69/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0403 - acc: 0.8445 - val
Epoch 70/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0393 - acc: 0.8458 - val
Epoch 71/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0390 - acc: 0.8453 - val
Epoch 72/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0368 - acc: 0.8460 - val
Epoch 73/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0352 - acc: 0.8465 - val
Epoch 74/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0378 - acc: 0.8453 - val
Epoch 75/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0348 - acc: 0.8469 - val
Epoch 76/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0356 - acc: 0.8466 - val
```

```
Epoch 77/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0360 - acc: 0.8457 - val
Epoch 78/100
50000/50000 [==============================] - 3s 58us/step - loss: 1.0315 - acc: 0.8492 - val
Epoch 79/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0339 - acc: 0.8454 - val
Epoch 80/100
50000/50000 [==============================] - 3s 61us/step - loss: 1.0312 - acc: 0.8473 - val
Epoch 81/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0323 - acc: 0.8462 - val
Epoch 82/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0309 - acc: 0.8466 - val
Epoch 83/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0306 - acc: 0.8462 - val
Epoch 84/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0292 - acc: 0.8480 - val
Epoch 85/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0307 - acc: 0.8452 - val
Epoch 86/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0292 - acc: 0.8471 - val
Epoch 87/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0296 - acc: 0.8467 - val
Epoch 88/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0293 - acc: 0.8473 - val
Epoch 89/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0277 - acc: 0.8493 - val
Epoch 90/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0273 - acc: 0.8464 - val
Epoch 91/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0269 - acc: 0.8480 - val
Epoch 92/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0277 - acc: 0.8478 - val
Epoch 93/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0247 - acc: 0.8469 - val
Epoch 94/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0250 - acc: 0.8473 - val
Epoch 95/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0211 - acc: 0.8508 - val
Epoch 96/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0258 - acc: 0.8483 - val
Epoch 97/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0220 - acc: 0.8491 - val
Epoch 98/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0249 - acc: 0.8482 - val
Epoch 99/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0209 - acc: 0.8498 - val
Epoch 100/100
50000/50000 [==============================] - 3s 59us/step - loss: 1.0233 - acc: 0.8472 - val
```

```
In [52]: network_alt8 = models.Sequential()
         network_alt8.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel_
         network_alt8.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt8.add(layers.Dense(10, activation='softmax'))
         network_alt8.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['
         result_alt8 = network_alt8.fit(x_train, y_train, validation_data=(x_valid, y_valid), e

Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 3s 64us/step - loss: 9.0335 - acc: 0.6663 - val_
Epoch 2/100
50000/50000 [==============================] - 2s 41us/step - loss: 2.1934 - acc: 0.7398 - val_
Epoch 3/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.5122 - acc: 0.7680 - val_
Epoch 4/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.3061 - acc: 0.7834 - val_
Epoch 5/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.1944 - acc: 0.7952 - val_
Epoch 6/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.1315 - acc: 0.8003 - val_
Epoch 7/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0929 - acc: 0.8088 - val_
Epoch 8/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0636 - acc: 0.8134 - val_
Epoch 9/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0451 - acc: 0.8179 - val_
Epoch 10/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0303 - acc: 0.8204 - val_
Epoch 11/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0187 - acc: 0.8227 - val_
Epoch 12/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0075 - acc: 0.8261 - val_
Epoch 13/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9956 - acc: 0.8285 - val_
Epoch 14/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9882 - acc: 0.8300 - val_
Epoch 15/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9811 - acc: 0.8333 - val_
Epoch 16/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9773 - acc: 0.8311 - val_
Epoch 17/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9709 - acc: 0.8328 - val_
Epoch 18/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9642 - acc: 0.8352 - val_
Epoch 19/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9608 - acc: 0.8357 - val_
```

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Epoch 20/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9553 - acc: 0.8370 - val
Epoch 21/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9520 - acc: 0.8358 - val
Epoch 22/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9485 - acc: 0.8372 - val
Epoch 23/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9411 - acc: 0.8401 - val
Epoch 24/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9389 - acc: 0.8402 - val
Epoch 25/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.9346 - acc: 0.8397 - val
Epoch 26/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.9290 - acc: 0.8395 - val
Epoch 27/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9265 - acc: 0.8438 - val
Epoch 28/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9219 - acc: 0.8420 - val
Epoch 29/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9210 - acc: 0.8416 - val
Epoch 30/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9172 - acc: 0.8417 - val
Epoch 31/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9129 - acc: 0.8440 - val
Epoch 32/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.9114 - acc: 0.8436 - val
Epoch 33/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9109 - acc: 0.8440 - val
Epoch 34/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9081 - acc: 0.8456 - val
Epoch 35/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9062 - acc: 0.8447 - val
Epoch 36/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9047 - acc: 0.8458 - val
Epoch 37/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.9014 - acc: 0.8454 - val
Epoch 38/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8994 - acc: 0.8463 - val
Epoch 39/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8984 - acc: 0.8461 - val
Epoch 40/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8964 - acc: 0.8468 - val
Epoch 41/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8931 - acc: 0.8464 - val
Epoch 42/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8923 - acc: 0.8466 - val
Epoch 43/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8906 - acc: 0.8482 - val
```

```
Epoch 44/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8904 - acc: 0.8487 - val
Epoch 45/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8878 - acc: 0.8489 - val
Epoch 46/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8894 - acc: 0.8475 - val
Epoch 47/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8866 - acc: 0.8487 - val
Epoch 48/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8881 - acc: 0.8488 - val
Epoch 49/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8857 - acc: 0.8482 - val
Epoch 50/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8832 - acc: 0.8498 - val
Epoch 51/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8849 - acc: 0.8492 - val
Epoch 52/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8810 - acc: 0.8505 - val
Epoch 53/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8811 - acc: 0.8510 - val
Epoch 54/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8814 - acc: 0.8493 - val
Epoch 55/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8797 - acc: 0.8499 - val
Epoch 56/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8799 - acc: 0.8498 - val
Epoch 57/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8794 - acc: 0.8496 - val
Epoch 58/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8758 - acc: 0.8506 - val
Epoch 59/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8760 - acc: 0.8520 - val
Epoch 60/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8733 - acc: 0.8514 - val
Epoch 61/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8744 - acc: 0.8524 - val
Epoch 62/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8719 - acc: 0.8529 - val
Epoch 63/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8748 - acc: 0.8522 - val
Epoch 64/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8708 - acc: 0.8534 - val
Epoch 65/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8694 - acc: 0.8527 - val
Epoch 66/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8724 - acc: 0.8522 - val
Epoch 67/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8690 - acc: 0.8532 - val
```

```
Epoch 68/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8697 - acc: 0.8518 - val
Epoch 69/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8682 - acc: 0.8520 - val
Epoch 70/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8698 - acc: 0.8521 - val
Epoch 71/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8692 - acc: 0.8515 - val
Epoch 72/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8660 - acc: 0.8536 - val
Epoch 73/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8665 - acc: 0.8537 - val
Epoch 74/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8640 - acc: 0.8549 - val
Epoch 75/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8657 - acc: 0.8532 - val
Epoch 76/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8636 - acc: 0.8551 - val
Epoch 77/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8660 - acc: 0.8530 - val
Epoch 78/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8644 - acc: 0.8535 - val
Epoch 79/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8615 - acc: 0.8548 - val
Epoch 80/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.8639 - acc: 0.8543 - val
Epoch 81/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.8647 - acc: 0.8539 - val
Epoch 82/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8619 - acc: 0.8543 - val
Epoch 83/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8616 - acc: 0.8537 - val
Epoch 84/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8612 - acc: 0.8558 - val
Epoch 85/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8599 - acc: 0.8549 - val
Epoch 86/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8620 - acc: 0.8547 - val
Epoch 87/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8584 - acc: 0.8544 - val
Epoch 88/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8619 - acc: 0.8544 - val
Epoch 89/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8566 - acc: 0.8558 - val
Epoch 90/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8600 - acc: 0.8544 - val
Epoch 91/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8584 - acc: 0.8537 - val
```

```
Epoch 92/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8564 - acc: 0.8559 - val
Epoch 93/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8606 - acc: 0.8537 - val
Epoch 94/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8572 - acc: 0.8543 - val
Epoch 95/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8557 - acc: 0.8549 - val
Epoch 96/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8549 - acc: 0.8558 - val
Epoch 97/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8572 - acc: 0.8544 - val
Epoch 98/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8562 - acc: 0.8553 - val
Epoch 99/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8563 - acc: 0.8551 - val
Epoch 100/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8530 - acc: 0.8556 - val
```

```
In [56]: network_alt9 = models.Sequential()
         network_alt9.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel_r
         network_alt9.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt9.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt9.add(layers.Dense(10, activation='softmax'))
         network_alt9.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['a
         result_alt9 = network_alt9.fit(x_train, y_train, validation_data=(x_valid, y_valid), e
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/100
50000/50000 [==============================] - 4s 89us/step - loss: 6.4294 - acc: 0.6480 - val
Epoch 2/100
50000/50000 [==============================] - 3s 64us/step - loss: 2.1524 - acc: 0.7352 - val
Epoch 3/100
50000/50000 [==============================] - 3s 62us/step - loss: 1.4806 - acc: 0.7615 - val
Epoch 4/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.2112 - acc: 0.7848 - val
Epoch 5/100
50000/50000 [==============================] - 3s 60us/step - loss: 1.0842 - acc: 0.7912 - val
Epoch 6/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.9903 - acc: 0.8032 - val
Epoch 7/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.9396 - acc: 0.8108 - val
Epoch 8/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.9047 - acc: 0.8151 - val
Epoch 9/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8803 - acc: 0.8193 - val
Epoch 10/100
```

```
50000/50000 [==============================] - 3s 59us/step - loss: 0.8590 - acc: 0.8263 - val
Epoch 11/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8458 - acc: 0.8261 - val
Epoch 12/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8286 - acc: 0.8312 - val
Epoch 13/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8156 - acc: 0.8327 - val
Epoch 14/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8103 - acc: 0.8322 - val
Epoch 15/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.8034 - acc: 0.8346 - val
Epoch 16/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7968 - acc: 0.8365 - val
Epoch 17/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7878 - acc: 0.8385 - val
Epoch 18/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7840 - acc: 0.8397 - val
Epoch 19/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7817 - acc: 0.8406 - val
Epoch 20/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7728 - acc: 0.8409 - val
Epoch 21/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7707 - acc: 0.8425 - val
Epoch 22/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7665 - acc: 0.8436 - val
Epoch 23/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7636 - acc: 0.8436 - val
Epoch 24/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7614 - acc: 0.8447 - val
Epoch 25/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7592 - acc: 0.8464 - val
Epoch 26/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7545 - acc: 0.8466 - val
Epoch 27/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7517 - acc: 0.8481 - val
Epoch 28/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7506 - acc: 0.8483 - val
Epoch 29/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.7462 - acc: 0.8491 - val
Epoch 30/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7459 - acc: 0.8487 - val
Epoch 31/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7435 - acc: 0.8484 - val
Epoch 32/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7457 - acc: 0.8484 - val
Epoch 33/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7398 - acc: 0.8508 - val
Epoch 34/100
```

```
50000/50000 [==============================] - 3s 60us/step - loss: 0.7388 - acc: 0.8513 - val
Epoch 35/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7367 - acc: 0.8512 - val
Epoch 36/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.7351 - acc: 0.8504 - val
Epoch 37/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.7339 - acc: 0.8518 - val
Epoch 38/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.7327 - acc: 0.8503 - val
Epoch 39/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7306 - acc: 0.8537 - val
Epoch 40/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7308 - acc: 0.8520 - val
Epoch 41/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7256 - acc: 0.8542 - val
Epoch 42/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.7286 - acc: 0.8527 - val
Epoch 43/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7257 - acc: 0.8554 - val
Epoch 44/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7264 - acc: 0.8538 - val
Epoch 45/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7232 - acc: 0.8546 - val
Epoch 46/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7223 - acc: 0.8547 - val
Epoch 47/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7246 - acc: 0.8556 - val
Epoch 48/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7225 - acc: 0.8542 - val
Epoch 49/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7227 - acc: 0.8550 - val
Epoch 50/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7188 - acc: 0.8566 - val
Epoch 51/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7169 - acc: 0.8544 - val
Epoch 52/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7172 - acc: 0.8572 - val
Epoch 53/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7168 - acc: 0.8571 - val
Epoch 54/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7162 - acc: 0.8571 - val
Epoch 55/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7142 - acc: 0.8577 - val
Epoch 56/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7164 - acc: 0.8560 - val
Epoch 57/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7150 - acc: 0.8571 - val
Epoch 58/100
```

```
50000/50000 [==============================] - 3s 62us/step - loss: 0.7141 - acc: 0.8571 - val
Epoch 59/100
50000/50000 [==============================] - 3s 62us/step - loss: 0.7126 - acc: 0.8594 - val
Epoch 60/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7153 - acc: 0.8561 - val
Epoch 61/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7116 - acc: 0.8580 - val
Epoch 62/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7097 - acc: 0.8593 - val
Epoch 63/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7102 - acc: 0.8575 - val
Epoch 64/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7079 - acc: 0.8600 - val
Epoch 65/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7079 - acc: 0.8597 - val
Epoch 66/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7089 - acc: 0.8586 - val
Epoch 67/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7082 - acc: 0.8588 - val
Epoch 68/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7055 - acc: 0.8601 - val
Epoch 69/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7052 - acc: 0.8601 - val
Epoch 70/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7038 - acc: 0.8607 - val
Epoch 71/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7039 - acc: 0.8603 - val
Epoch 72/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7040 - acc: 0.8614 - val
Epoch 73/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7018 - acc: 0.8615 - val
Epoch 74/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7033 - acc: 0.8610 - val
Epoch 75/100
50000/50000 [==============================] - 3s 59us/step - loss: 0.7008 - acc: 0.8613 - val
Epoch 76/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7041 - acc: 0.8610 - val
Epoch 77/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7011 - acc: 0.8609 - val
Epoch 78/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7027 - acc: 0.8616 - val
Epoch 79/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7007 - acc: 0.8602 - val
Epoch 80/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6997 - acc: 0.8627 - val
Epoch 81/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.7029 - acc: 0.8597 - val
Epoch 82/100
```

```
50000/50000 [==============================] - 3s 60us/step - loss: 0.6991 - acc: 0.8621 - val
Epoch 83/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6958 - acc: 0.8633 - val
Epoch 84/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6978 - acc: 0.8615 - val
Epoch 85/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6955 - acc: 0.8625 - val
Epoch 86/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6970 - acc: 0.8630 - val
Epoch 87/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6968 - acc: 0.8618 - val
Epoch 88/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6964 - acc: 0.8628 - val
Epoch 89/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6929 - acc: 0.8633 - val
Epoch 90/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6946 - acc: 0.8641 - val
Epoch 91/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6926 - acc: 0.8643 - val
Epoch 92/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6933 - acc: 0.8641 - val
Epoch 93/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6923 - acc: 0.8637 - val
Epoch 94/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6934 - acc: 0.8630 - val
Epoch 95/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6934 - acc: 0.8613 - val
Epoch 96/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6959 - acc: 0.8612 - val
Epoch 97/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6922 - acc: 0.8639 - val
Epoch 98/100
50000/50000 [==============================] - 3s 60us/step - loss: 0.6915 - acc: 0.8636 - val
Epoch 99/100
50000/50000 [==============================] - 3s 63us/step - loss: 0.6914 - acc: 0.8635 - val
Epoch 100/100
50000/50000 [==============================] - 3s 61us/step - loss: 0.6874 - acc: 0.8649 - val
```

```
In [54]: network_alt10 = models.Sequential()
         network_alt10.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,), kernel
         network_alt10.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers
         network_alt10.add(layers.Dense(10, activation='softmax'))
         network_alt10.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=[
         result_alt10 = network_alt10.fit(x_train, y_train, validation_data=(x_valid, y_valid)

Train on 50000 samples, validate on 10000 samples
Epoch 1/100
```

```
50000/50000 [==============================] - 3s 68us/step - loss: 6.2714 - acc: 0.6804 - val
Epoch 2/100
50000/50000 [==============================] - 2s 42us/step - loss: 2.0180 - acc: 0.7379 - val
Epoch 3/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.3955 - acc: 0.7640 - val
Epoch 4/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.1605 - acc: 0.7830 - val
Epoch 5/100
50000/50000 [==============================] - 2s 42us/step - loss: 1.0283 - acc: 0.7983 - val
Epoch 6/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9634 - acc: 0.8048 - val
Epoch 7/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.9073 - acc: 0.8158 - val
Epoch 8/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8738 - acc: 0.8216 - val
Epoch 9/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8462 - acc: 0.8264 - val
Epoch 10/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.8250 - acc: 0.8294 - val
Epoch 11/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.8088 - acc: 0.8323 - val
Epoch 12/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7960 - acc: 0.8359 - val
Epoch 13/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7867 - acc: 0.8375 - val
Epoch 14/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7760 - acc: 0.8414 - val
Epoch 15/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7730 - acc: 0.8401 - val
Epoch 16/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7640 - acc: 0.8429 - val
Epoch 17/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7602 - acc: 0.8437 - val
Epoch 18/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7535 - acc: 0.8462 - val
Epoch 19/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7527 - acc: 0.8457 - val
Epoch 20/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7482 - acc: 0.8451 - val
Epoch 21/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.7446 - acc: 0.8474 - val
Epoch 22/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7420 - acc: 0.8461 - val
Epoch 23/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7380 - acc: 0.8492 - val
Epoch 24/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7352 - acc: 0.8510 - val
Epoch 25/100
```

```
50000/50000 [==============================] - 2s 44us/step - loss: 0.7336 - acc: 0.8500 - val
Epoch 26/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7304 - acc: 0.8512 - val
Epoch 27/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7309 - acc: 0.8495 - val
Epoch 28/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7271 - acc: 0.8518 - val
Epoch 29/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7261 - acc: 0.8509 - val
Epoch 30/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7242 - acc: 0.8533 - val
Epoch 31/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7224 - acc: 0.8533 - val
Epoch 32/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7191 - acc: 0.8548 - val
Epoch 33/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7172 - acc: 0.8533 - val
Epoch 34/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7189 - acc: 0.8530 - val
Epoch 35/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7178 - acc: 0.8539 - val
Epoch 36/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7129 - acc: 0.8538 - val
Epoch 37/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7137 - acc: 0.8545 - val
Epoch 38/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7130 - acc: 0.8549 - val
Epoch 39/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7093 - acc: 0.8563 - val
Epoch 40/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7097 - acc: 0.8561 - val
Epoch 41/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7114 - acc: 0.8542 - val
Epoch 42/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7069 - acc: 0.8550 - val
Epoch 43/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.7077 - acc: 0.8562 - val
Epoch 44/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7015 - acc: 0.8566 - val
Epoch 45/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7064 - acc: 0.8564 - val
Epoch 46/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7023 - acc: 0.8566 - val
Epoch 47/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.7024 - acc: 0.8581 - val
Epoch 48/100
50000/50000 [==============================] - 2s 48us/step - loss: 0.7007 - acc: 0.8605 - val
Epoch 49/100
```

```
50000/50000 [==============================] - 2s 47us/step - loss: 0.7017 - acc: 0.8580 - val
Epoch 50/100
50000/50000 [==============================] - 2s 46us/step - loss: 0.7021 - acc: 0.8575 - val
Epoch 51/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6983 - acc: 0.8584 - val
Epoch 52/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6972 - acc: 0.8585 - val
Epoch 53/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6968 - acc: 0.8603 - val
Epoch 54/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6977 - acc: 0.8597 - val
Epoch 55/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6973 - acc: 0.8594 - val
Epoch 56/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6958 - acc: 0.8603 - val
Epoch 57/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6922 - acc: 0.8622 - val
Epoch 58/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6928 - acc: 0.8610 - val
Epoch 59/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6924 - acc: 0.8600 - val
Epoch 60/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6924 - acc: 0.8613 - val
Epoch 61/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6925 - acc: 0.8610 - val
Epoch 62/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6911 - acc: 0.8626 - val
Epoch 63/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6925 - acc: 0.8604 - val
Epoch 64/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6918 - acc: 0.8610 - val
Epoch 65/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6905 - acc: 0.8603 - val
Epoch 66/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6880 - acc: 0.8626 - val
Epoch 67/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6892 - acc: 0.8626 - val
Epoch 68/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6882 - acc: 0.8623 - val
Epoch 69/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6866 - acc: 0.8635 - val
Epoch 70/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6848 - acc: 0.8638 - val
Epoch 71/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6867 - acc: 0.8620 - val
Epoch 72/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6874 - acc: 0.8615 - val
Epoch 73/100
```

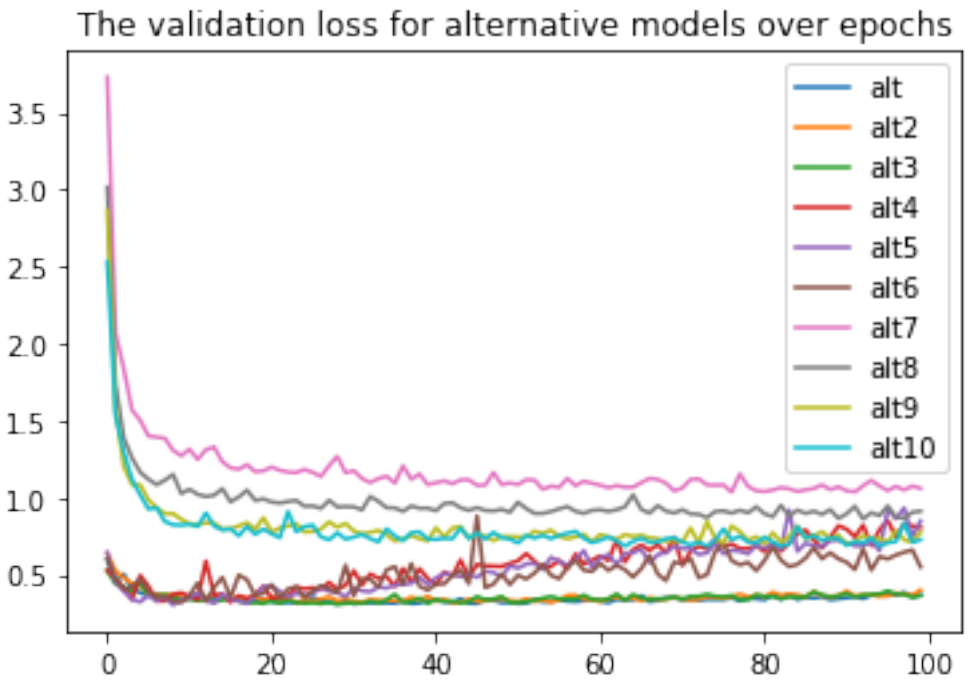
```
50000/50000 [==============================] - 2s 42us/step - loss: 0.6838 - acc: 0.8639 - val
Epoch 74/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6844 - acc: 0.8629 - val
Epoch 75/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6814 - acc: 0.8643 - val
Epoch 76/100
50000/50000 [==============================] - 2s 45us/step - loss: 0.6829 - acc: 0.8639 - val
Epoch 77/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6823 - acc: 0.8644 - val
Epoch 78/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6853 - acc: 0.8627 - val
Epoch 79/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6798 - acc: 0.8653 - val
Epoch 80/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6827 - acc: 0.8650 - val
Epoch 81/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6774 - acc: 0.8659 - val
Epoch 82/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6789 - acc: 0.8646 - val
Epoch 83/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6810 - acc: 0.8653 - val
Epoch 84/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6789 - acc: 0.8656 - val
Epoch 85/100
50000/50000 [==============================] - 2s 44us/step - loss: 0.6805 - acc: 0.8653 - val
Epoch 86/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6787 - acc: 0.8651 - val
Epoch 87/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6801 - acc: 0.8639 - val
Epoch 88/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6787 - acc: 0.8656 - val
Epoch 89/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6794 - acc: 0.8655 - val
Epoch 90/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6791 - acc: 0.8655 - val
Epoch 91/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6745 - acc: 0.8674 - val
Epoch 92/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6771 - acc: 0.8660 - val
Epoch 93/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6730 - acc: 0.8676 - val
Epoch 94/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6738 - acc: 0.8682 - val
Epoch 95/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6761 - acc: 0.8667 - val
Epoch 96/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6761 - acc: 0.8646 - val
Epoch 97/100
```

```
50000/50000 [==============================] - 2s 43us/step - loss: 0.6717 - acc: 0.8667 - val
Epoch 98/100
50000/50000 [==============================] - 2s 42us/step - loss: 0.6726 - acc: 0.8664 - val
Epoch 99/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6740 - acc: 0.8668 - val
Epoch 100/100
50000/50000 [==============================] - 2s 43us/step - loss: 0.6739 - acc: 0.8674 - val
```

```
In [57]: result_ls = [result_alt, result_alt2, result_alt3, result_alt4, result_alt5,\
                      result_alt6, result_alt7, result_alt8, result_alt9, result_alt10]

         for rs in result_ls:
             vl = rs.history['val_loss'][:100]
             plt.plot(vl)

         plt.legend(['alt', 'alt2', 'alt3', 'alt4', 'alt5', 'alt6', 'alt7', 'alt8', 'alt9', 'al
         plt.title('The validation loss for alternative models over epochs')
         plt.show()
```



From above plot we can see that alternative model 3 (3-layer model with drop out) has the lowest validation loss and therefore performs the best.

4. Final model

```
In [65]: (x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()
         x_train = x_train.reshape([60000, 28*28]).astype('float32')/255
```

```
x_test = x_test.reshape([10000, 28*28]).astype('float32')/255
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)

best_model = network_alt3.fit(x_train, y_train, epochs=22, batch_size=512)
```

```
Epoch 1/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1980 - acc: 0.9323
Epoch 2/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1910 - acc: 0.9345
Epoch 3/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1936 - acc: 0.9325
Epoch 4/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1925 - acc: 0.9338
Epoch 5/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1954 - acc: 0.9347
Epoch 6/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1897 - acc: 0.9334
Epoch 7/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1877 - acc: 0.9340
Epoch 8/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1872 - acc: 0.9351
Epoch 9/22
60000/60000 [==============================] - 2s 40us/step - loss: 0.1895 - acc: 0.9350
Epoch 10/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1843 - acc: 0.9363
Epoch 11/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1920 - acc: 0.9353
Epoch 12/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1907 - acc: 0.9346
Epoch 13/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1897 - acc: 0.9356
Epoch 14/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1894 - acc: 0.9354
Epoch 15/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1833 - acc: 0.9364
Epoch 16/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1890 - acc: 0.9367
Epoch 17/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1849 - acc: 0.9361
Epoch 18/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1822 - acc: 0.9365
Epoch 19/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1824 - acc: 0.9358
Epoch 20/22
60000/60000 [==============================] - 3s 44us/step - loss: 0.1828 - acc: 0.9365
Epoch 21/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1807 - acc: 0.9380
```

```
Epoch 22/22
60000/60000 [==============================] - 2s 41us/step - loss: 0.1864 - acc: 0.9363
```

```
In [66]: network_alt3.evaluate(x_test, y_test)
```

```
10000/10000 [==============================] - 0s 46us/step
```

```
Out[66]: [0.45949229189306495, 0.8962]
```

The test set loss and accuracy of the selected model are 0.4595 and 0.8962 respectively. Comparing to its validation set loss and accuracy of 0.3656 and 0.9008, the model generalizes well with only slightly lower accuracy. Comparing to other models, this model has less complexity with only three layers with dropout. As a result, this model is more suitable for this low-dimensional dattaset. Other more complicated complex models may lead to overfitting.

```
In [ ]:
```