PS3 (2)

May 16, 2018

1 Part 1: Image classification

1. Set your random seed to 1234
2. Load the MNIST dataset

```
In [3]: import random
        from keras.datasets import mnist
        from keras import models
        from keras import layers
        from keras import regularizers
        from keras.utils import to_categorical
        from sklearn.model_selection import train_test_split
        import matplotlib.pyplot as plt
        %matplotlib inline

        random.seed(1234)
        (train_images, train_labels), (test_images, test_labels) = mnist.load_data()
        train_images = train_images.reshape((60000, 28 * 28)).astype('float32') / 255
        test_images = test_images.reshape((10000, 28 * 28)).astype('float32') / 255
        train_labels = to_categorical(train_labels)
        test_labels = to_categorical(test_labels)
        train_images, valid_images, train_labels, valid_labels = train_test_split(train_images
```

```
Using TensorFlow backend.


Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 4s 0us/step
```

3.Implement a series of neural network models

```
i.Initial test
```

```
In [6]: network_org = models.Sequential()
        network_org.add(layers.Dense(512, activation='relu', input_shape= (28 * 28,)))
        network_org.add(layers.Dense(512, activation='relu'))
        network_org.add(layers.Dense(512, activation='relu'))
```

```
        network_org.add(layers.Dense(512, activation='relu'))
        network_org.add(layers.Dense(10, activation='softmax'))
        network_org.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['ac
        result_org = network_org.fit(train_images, train_labels,validation_data=(valid_images,
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.5068 - acc: 0.8360 - val
Epoch 2/200
50000/50000 [==============================] - 5s 96us/step - loss: 0.1585 - acc: 0.9526 - val_
Epoch 3/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0972 - acc: 0.9702 - val_
Epoch 4/200
50000/50000 [==============================] - 5s 95us/step - loss: 0.0661 - acc: 0.9799 - val_
Epoch 5/200
50000/50000 [==============================] - 5s 95us/step - loss: 0.0463 - acc: 0.9859 - val_
Epoch 6/200
50000/50000 [==============================] - 5s 96us/step - loss: 0.0356 - acc: 0.9894 - val_
Epoch 7/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0282 - acc: 0.9912 - val_
Epoch 8/200
50000/50000 [==============================] - 5s 109us/step - loss: 0.0249 - acc: 0.9922 - val
Epoch 9/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0224 - acc: 0.9936 - val
Epoch 10/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0164 - acc: 0.9951 - val_
Epoch 11/200
50000/50000 [==============================] - 5s 96us/step - loss: 0.0168 - acc: 0.9951 - val_
Epoch 12/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0163 - acc: 0.9955 - val
Epoch 13/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0119 - acc: 0.9966 - val
Epoch 14/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0146 - acc: 0.9962 - val
Epoch 15/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.0123 - acc: 0.9971 - val
Epoch 16/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.0119 - acc: 0.9971 - val
Epoch 17/200
50000/50000 [==============================] - 5s 105us/step - loss: 0.0088 - acc: 0.9975 - val
Epoch 18/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0107 - acc: 0.9973 - val
Epoch 19/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0094 - acc: 0.9975 - val
Epoch 20/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0101 - acc: 0.9978 - val
Epoch 21/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0089 - acc: 0.9977 - val_
```

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Epoch 22/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0110 - acc: 0.9973 - val
Epoch 23/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.0063 - acc: 0.9982 - val
Epoch 24/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0095 - acc: 0.9979 - val
Epoch 25/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0077 - acc: 0.9982 - val
Epoch 26/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0071 - acc: 0.9985 - val
Epoch 27/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0085 - acc: 0.9978 - val_
Epoch 28/200
50000/50000 [==============================] - 5s 97us/step - loss: 0.0106 - acc: 0.9979 - val_
Epoch 29/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0069 - acc: 0.9984 - val_
Epoch 30/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0067 - acc: 0.9983 - val_
Epoch 31/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0067 - acc: 0.9986 - val_
Epoch 32/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0090 - acc: 0.9982 - val_
Epoch 33/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0077 - acc: 0.9985 - val_
Epoch 34/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0065 - acc: 0.9984 - val_
Epoch 35/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0061 - acc: 0.9988 - val_
Epoch 36/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0068 - acc: 0.9986 - val_
Epoch 37/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0075 - acc: 0.9986 - val_
Epoch 38/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0050 - acc: 0.9989 - val_
Epoch 39/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0092 - acc: 0.9982 - val_
Epoch 40/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0084 - acc: 0.9984 - val_
Epoch 41/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0070 - acc: 0.9988 - val_
Epoch 42/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.0077 - acc: 0.9988 - val
Epoch 43/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.0083 - acc: 0.9985 - val
Epoch 44/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0084 - acc: 0.9986 - val
Epoch 45/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0059 - acc: 0.9989 - val
```

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Epoch 46/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0108 - acc: 0.9983 - val
Epoch 47/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0064 - acc: 0.9987 - val
Epoch 48/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0067 - acc: 0.9987 - val_
Epoch 49/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0067 - acc: 0.9986 - val_
Epoch 50/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0084 - acc: 0.9986 - val_
Epoch 51/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0070 - acc: 0.9990 - val_
Epoch 52/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0099 - acc: 0.9987 - val_
Epoch 53/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0068 - acc: 0.9990 - val
Epoch 54/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.0065 - acc: 0.9988 - val
Epoch 55/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.0055 - acc: 0.9992 - val
Epoch 56/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0056 - acc: 0.9992 - val_
Epoch 57/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0056 - acc: 0.9990 - val_
Epoch 58/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0095 - acc: 0.9986 - val_
Epoch 59/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0054 - acc: 0.9992 - val_
Epoch 60/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0052 - acc: 0.9990 - val
Epoch 61/200
50000/50000 [==============================] - 5s 97us/step - loss: 0.0075 - acc: 0.9986 - val_
Epoch 62/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0079 - acc: 0.9988 - val_
Epoch 63/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0056 - acc: 0.9989 - val_
Epoch 64/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0072 - acc: 0.9989 - val
Epoch 65/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0064 - acc: 0.9990 - val_
Epoch 66/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0080 - acc: 0.9988 - val_
Epoch 67/200
50000/50000 [==============================] - 4s 90us/step - loss: 0.0062 - acc: 0.9991 - val_
Epoch 68/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0057 - acc: 0.9992 - val_
Epoch 69/200
50000/50000 [==============================] - 4s 84us/step - loss: 0.0072 - acc: 0.9989 - val_
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Epoch 70/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0050 - acc: 0.9988 - val
Epoch 71/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0076 - acc: 0.9987 - val
Epoch 72/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0039 - acc: 0.9994 - val
Epoch 73/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0060 - acc: 0.9990 - val
Epoch 74/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0065 - acc: 0.9989 - val
Epoch 75/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0067 - acc: 0.9990 - val
Epoch 76/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0054 - acc: 0.9993 - val
Epoch 77/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0082 - acc: 0.9988 - val
Epoch 78/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0052 - acc: 0.9993 - val
Epoch 79/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0067 - acc: 0.9989 - val
Epoch 80/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0056 - acc: 0.9992 - val
Epoch 81/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0074 - acc: 0.9989 - val
Epoch 82/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0074 - acc: 0.9987 - val
Epoch 83/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0067 - acc: 0.9992 - val
Epoch 84/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0097 - acc: 0.9989 - val
Epoch 85/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0105 - acc: 0.9987 - val
Epoch 86/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0081 - acc: 0.9988 - val
Epoch 87/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0051 - acc: 0.9992 - val
Epoch 88/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0070 - acc: 0.9988 - val
Epoch 89/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0040 - acc: 0.9992 - val
Epoch 90/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0061 - acc: 0.9990 - val
Epoch 91/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0027 - acc: 0.9995 - val
Epoch 92/200
50000/50000 [==============================] - 4s 85us/step - loss: 0.0068 - acc: 0.9991 - val
Epoch 93/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0052 - acc: 0.9994 - val
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Epoch 94/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0092 - acc: 0.9988 - val
Epoch 95/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0067 - acc: 0.9990 - val
Epoch 96/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0060 - acc: 0.9991 - va
Epoch 97/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0061 - acc: 0.9991 - va
Epoch 98/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0076 - acc: 0.9989 - val
Epoch 99/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0080 - acc: 0.9991 - val
Epoch 100/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0078 - acc: 0.9990 - val
Epoch 101/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0068 - acc: 0.9990 - val
Epoch 102/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0072 - acc: 0.9990 - val
Epoch 103/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0071 - acc: 0.9989 - val
Epoch 104/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0074 - acc: 0.9991 - va
Epoch 105/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0048 - acc: 0.9993 - va
Epoch 106/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0079 - acc: 0.9991 - va
Epoch 107/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.0062 - acc: 0.9990 - va
Epoch 108/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0103 - acc: 0.9989 - val
Epoch 109/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0052 - acc: 0.9992 - val
Epoch 110/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0070 - acc: 0.9989 - va
Epoch 111/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0070 - acc: 0.9990 - val
Epoch 112/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0047 - acc: 0.9993 - va
Epoch 113/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0091 - acc: 0.9990 - va
Epoch 114/200
50000/50000 [==============================] - 5s 109us/step - loss: 0.0071 - acc: 0.9991 - va
Epoch 115/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.0041 - acc: 0.9994 - va
Epoch 116/200
50000/50000 [==============================] - 5s 109us/step - loss: 0.0066 - acc: 0.9991 - va
Epoch 117/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.0080 - acc: 0.9990 - va
```

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Epoch 118/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0048 - acc: 0.9993 - val
Epoch 119/200
50000/50000 [==============================] - 5s 95us/step - loss: 0.0035 - acc: 0.9995 - val_
Epoch 120/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0107 - acc: 0.9988 - val
Epoch 121/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.0124 - acc: 0.9986 - val
Epoch 122/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0067 - acc: 0.9991 - val
Epoch 123/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.0096 - acc: 0.9987 - val
Epoch 124/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0044 - acc: 0.9993 - val
Epoch 125/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0055 - acc: 0.9993 - val_
Epoch 126/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0072 - acc: 0.9991 - val_
Epoch 127/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0065 - acc: 0.9991 - val_
Epoch 128/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0066 - acc: 0.9990 - val_
Epoch 129/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0102 - acc: 0.9988 - val_
Epoch 130/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0063 - acc: 0.9993 - val_
Epoch 131/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0090 - acc: 0.9988 - val_
Epoch 132/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0053 - acc: 0.9992 - val_
Epoch 133/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0051 - acc: 0.9992 - val
Epoch 134/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.0074 - acc: 0.9991 - val
Epoch 135/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0061 - acc: 0.9993 - val
Epoch 136/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0070 - acc: 0.9992 - val
Epoch 137/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.0038 - acc: 0.9995 - val
Epoch 138/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.0068 - acc: 0.9992 - val
Epoch 139/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0075 - acc: 0.9992 - val
Epoch 140/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.0025 - acc: 0.9996 - val
Epoch 141/200
50000/50000 [==============================] - 5s 109us/step - loss: 0.0041 - acc: 0.9994 - val
```

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Epoch 142/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.0070 - acc: 0.9991 - val
Epoch 143/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0050 - acc: 0.9994 - val
Epoch 144/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0067 - acc: 0.9992 - val
Epoch 145/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.0049 - acc: 0.9994 - val
Epoch 146/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.0024 - acc: 0.9997 - val
Epoch 147/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0062 - acc: 0.9992 - val_
Epoch 148/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0059 - acc: 0.9993 - val_
Epoch 149/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0070 - acc: 0.9992 - val_
Epoch 150/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0072 - acc: 0.9992 - val_
Epoch 151/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0044 - acc: 0.9994 - val_
Epoch 152/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0046 - acc: 0.9995 - val_
Epoch 153/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0094 - acc: 0.9989 - val_
Epoch 154/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0097 - acc: 0.9991 - val_
Epoch 155/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0041 - acc: 0.9995 - val_
Epoch 156/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0087 - acc: 0.9991 - val_
Epoch 157/200
50000/50000 [==============================] - 5s 93us/step - loss: 0.0068 - acc: 0.9993 - val_
Epoch 158/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0075 - acc: 0.9992 - val_
Epoch 159/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0044 - acc: 0.9993 - val_
Epoch 160/200
50000/50000 [==============================] - 5s 93us/step - loss: 0.0132 - acc: 0.9986 - val_
Epoch 161/200
50000/50000 [==============================] - 5s 92us/step - loss: 0.0048 - acc: 0.9993 - val_
Epoch 162/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0080 - acc: 0.9991 - val_
Epoch 163/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0028 - acc: 0.9995 - val_
Epoch 164/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0045 - acc: 0.9994 - val_
Epoch 165/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0033 - acc: 0.9995 - val_
```

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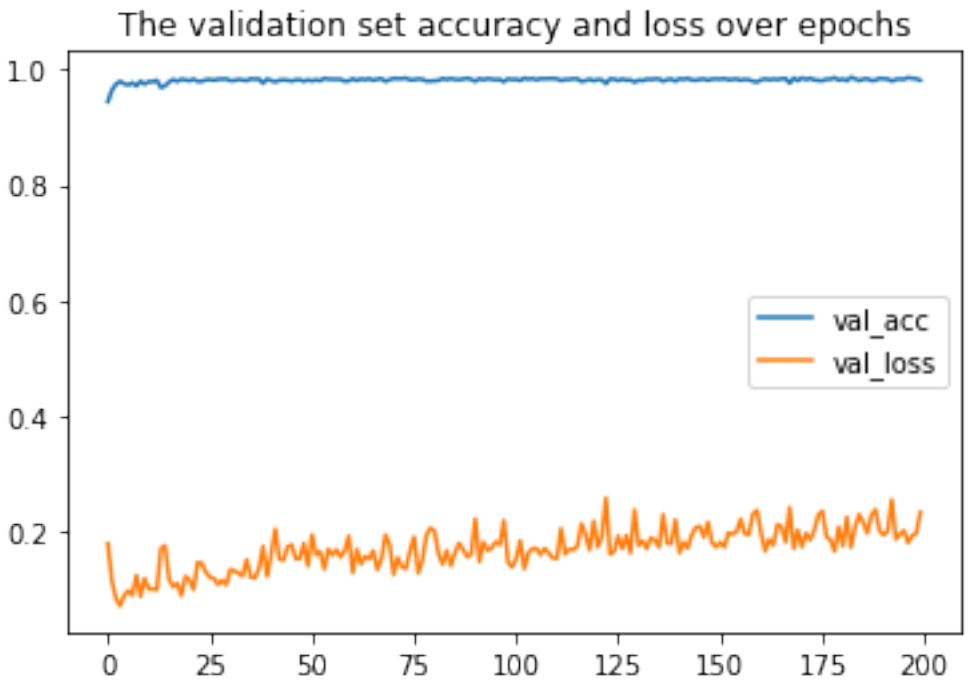
Epoch 166/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0047 - acc: 0.9995 - val
Epoch 167/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0078 - acc: 0.9991 - val
Epoch 168/200
50000/50000 [==============================] - 4s 90us/step - loss: 0.0086 - acc: 0.9990 - val
Epoch 169/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0049 - acc: 0.9994 - val
Epoch 170/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0056 - acc: 0.9993 - val
Epoch 171/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0065 - acc: 0.9992 - val
Epoch 172/200
50000/50000 [==============================] - 4s 89us/step - loss: 0.0068 - acc: 0.9993 - val
Epoch 173/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0063 - acc: 0.9994 - val
Epoch 174/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0110 - acc: 0.9990 - val
Epoch 175/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0070 - acc: 0.9993 - val
Epoch 176/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0079 - acc: 0.9992 - val
Epoch 177/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0086 - acc: 0.9991 - val
Epoch 178/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0072 - acc: 0.9992 - val
Epoch 179/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0026 - acc: 0.9997 - val
Epoch 180/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0068 - acc: 0.9993 - val
Epoch 181/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0042 - acc: 0.9994 - val
Epoch 182/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0038 - acc: 0.9994 - val
Epoch 183/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0020 - acc: 0.9996 - val
Epoch 184/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0041 - acc: 0.9994 - val
Epoch 185/200
50000/50000 [==============================] - 4s 88us/step - loss: 0.0054 - acc: 0.9993 - val
Epoch 186/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0039 - acc: 0.9996 - val
Epoch 187/200
50000/50000 [==============================] - 5s 93us/step - loss: 0.0053 - acc: 0.9994 - val
Epoch 188/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0087 - acc: 0.9990 - val
Epoch 189/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0068 - acc: 0.9994 - val
```

```
Epoch 190/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0057 - acc: 0.9993 - val
Epoch 191/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0065 - acc: 0.9992 - val
Epoch 192/200
50000/50000 [==============================] - 4s 86us/step - loss: 0.0043 - acc: 0.9994 - val
Epoch 193/200
50000/50000 [==============================] - 4s 87us/step - loss: 0.0049 - acc: 0.9994 - val
Epoch 194/200
50000/50000 [==============================] - 5s 91us/step - loss: 0.0105 - acc: 0.9990 - val
Epoch 195/200
50000/50000 [==============================] - 5s 90us/step - loss: 0.0036 - acc: 0.9996 - val
Epoch 196/200
50000/50000 [==============================] - 5s 98us/step - loss: 0.0062 - acc: 0.9994 - val
Epoch 197/200
50000/50000 [==============================] - 5s 95us/step - loss: 0.0040 - acc: 0.9995 - val
Epoch 198/200
50000/50000 [==============================] - 5s 94us/step - loss: 0.0026 - acc: 0.9997 - val
Epoch 199/200
50000/50000 [==============================] - 5s 94us/step - loss: 0.0027 - acc: 0.9997 - val
Epoch 200/200
50000/50000 [==============================] - 5s 94us/step - loss: 0.0073 - acc: 0.9993 - val
```

In [7]:
```
import matplotlib.pyplot as plt
%matplotlib inline

val_acc = result_org.history['val_acc']
val_loss = result_org.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 around epoch 42, the model starts to perform worse and worse based on the validation dataset.

ii. Implement dropout

```
In [9]: 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(train_images, train_labels,validation_data=(valid

Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.7243 - acc: 0.7620 - val
Epoch 2/200
50000/50000 [==============================] - 6s 130us/step - loss: 0.2653 - acc: 0.9216 - val
Epoch 3/200
50000/50000 [==============================] - 6s 128us/step - loss: 0.1967 - acc: 0.9450 - val
Epoch 4/200
```

```
50000/50000 [==============================] - 7s 130us/step - loss: 0.1660 - acc: 0.9535 - val
Epoch 5/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.1427 - acc: 0.9596 - val
Epoch 6/200
50000/50000 [==============================] - 6s 130us/step - loss: 0.1289 - acc: 0.9638 - val
Epoch 7/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.1162 - acc: 0.9673 - val
Epoch 8/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.1106 - acc: 0.9696 - val
Epoch 9/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.0976 - acc: 0.9725 - val
Epoch 10/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0951 - acc: 0.9739 - val
Epoch 11/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.0896 - acc: 0.9751 - val
Epoch 12/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0863 - acc: 0.9761 - val
Epoch 13/200
50000/50000 [==============================] - 6s 130us/step - loss: 0.0850 - acc: 0.9767 - val
Epoch 14/200
50000/50000 [==============================] - 7s 130us/step - loss: 0.0772 - acc: 0.9789 - val
Epoch 15/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0742 - acc: 0.9803 - val
Epoch 16/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0769 - acc: 0.9790 - val
Epoch 17/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0697 - acc: 0.9812 - val
Epoch 18/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0712 - acc: 0.9808 - val
Epoch 19/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0681 - acc: 0.9825 - val
Epoch 20/200
50000/50000 [==============================] - 6s 128us/step - loss: 0.0655 - acc: 0.9821 - val
Epoch 21/200
50000/50000 [==============================] - 7s 130us/step - loss: 0.0637 - acc: 0.9828 - val
Epoch 22/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.0619 - acc: 0.9837 - val
Epoch 23/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0615 - acc: 0.9841 - val
Epoch 24/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0599 - acc: 0.9841 - val
Epoch 25/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0602 - acc: 0.9845 - val
Epoch 26/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0568 - acc: 0.9852 - val
Epoch 27/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0604 - acc: 0.9849 - val
Epoch 28/200
```

```
50000/50000 [==============================] - 6s 123us/step - loss: 0.0568 - acc: 0.9849 - val
Epoch 29/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0568 - acc: 0.9855 - val
Epoch 30/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0598 - acc: 0.9857 - val
Epoch 31/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0531 - acc: 0.9864 - val
Epoch 32/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0562 - acc: 0.9865 - val
Epoch 33/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0545 - acc: 0.9868 - val
Epoch 34/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0528 - acc: 0.9868 - val
Epoch 35/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0567 - acc: 0.9866 - val
Epoch 36/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0519 - acc: 0.9870 - val
Epoch 37/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0506 - acc: 0.9879 - val
Epoch 38/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0539 - acc: 0.9870 - val
Epoch 39/200
50000/50000 [==============================] - 7s 147us/step - loss: 0.0519 - acc: 0.9877 - val
Epoch 40/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0515 - acc: 0.9883 - val
Epoch 41/200
50000/50000 [==============================] - 7s 147us/step - loss: 0.0553 - acc: 0.9876 - val
Epoch 42/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0525 - acc: 0.9884 - val
Epoch 43/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0527 - acc: 0.9883 - val
Epoch 44/200
50000/50000 [==============================] - 7s 130us/step - loss: 0.0542 - acc: 0.9879 - val
Epoch 45/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0504 - acc: 0.9888 - val
Epoch 46/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.0520 - acc: 0.9886 - val
Epoch 47/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.0522 - acc: 0.9888 - val
Epoch 48/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.0531 - acc: 0.9891 - val
Epoch 49/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.0516 - acc: 0.9885 - val
Epoch 50/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0484 - acc: 0.9896 - val
Epoch 51/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0540 - acc: 0.9886 - val
Epoch 52/200
```

```
50000/50000 [==============================] - 6s 115us/step - loss: 0.0545 - acc: 0.9883 - val
Epoch 53/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0486 - acc: 0.9890 - val
Epoch 54/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0522 - acc: 0.9895 - val
Epoch 55/200
50000/50000 [==============================] - 8s 157us/step - loss: 0.0536 - acc: 0.9884 - val
Epoch 56/200
50000/50000 [==============================] - 7s 148us/step - loss: 0.0526 - acc: 0.9884 - val
Epoch 57/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0512 - acc: 0.9894 - val
Epoch 58/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0472 - acc: 0.9894 - val
Epoch 59/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0511 - acc: 0.9891 - val
Epoch 60/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0475 - acc: 0.9897 - val
Epoch 61/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0571 - acc: 0.9885 - val
Epoch 62/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0552 - acc: 0.9892 - val
Epoch 63/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0530 - acc: 0.9898 - val
Epoch 64/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0510 - acc: 0.9899 - val
Epoch 65/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0512 - acc: 0.9897 - val
Epoch 66/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0526 - acc: 0.9901 - val
Epoch 67/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0474 - acc: 0.9908 - val
Epoch 68/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0510 - acc: 0.9907 - val
Epoch 69/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0560 - acc: 0.9900 - val
Epoch 70/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0541 - acc: 0.9899 - val
Epoch 71/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0555 - acc: 0.9899 - val
Epoch 72/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0518 - acc: 0.9901 - val
Epoch 73/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.0542 - acc: 0.9903 - val
Epoch 74/200
50000/50000 [==============================] - 6s 130us/step - loss: 0.0526 - acc: 0.9903 - val
Epoch 75/200
50000/50000 [==============================] - 8s 163us/step - loss: 0.0568 - acc: 0.9898 - val
Epoch 76/200
```

```
50000/50000 [==============================] - 8s 156us/step - loss: 0.0532 - acc: 0.9902 - val
Epoch 77/200
50000/50000 [==============================] - 8s 151us/step - loss: 0.0523 - acc: 0.9908 - val
Epoch 78/200
50000/50000 [==============================] - 8s 153us/step - loss: 0.0554 - acc: 0.9898 - val
Epoch 79/200
50000/50000 [==============================] - 7s 148us/step - loss: 0.0520 - acc: 0.9903 - val
Epoch 80/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0512 - acc: 0.9906 - val
Epoch 81/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0542 - acc: 0.9902 - val
Epoch 82/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0539 - acc: 0.9905 - val
Epoch 83/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0575 - acc: 0.9902 - val
Epoch 84/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0546 - acc: 0.9905 - val
Epoch 85/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0539 - acc: 0.9905 - val
Epoch 86/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0568 - acc: 0.9907 - val
Epoch 87/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0541 - acc: 0.9909 - val
Epoch 88/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0562 - acc: 0.9909 - val
Epoch 89/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0509 - acc: 0.9907 - val
Epoch 90/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0554 - acc: 0.9904 - val
Epoch 91/200
50000/50000 [==============================] - 8s 158us/step - loss: 0.0491 - acc: 0.9914 - val
Epoch 92/200
50000/50000 [==============================] - 8s 151us/step - loss: 0.0605 - acc: 0.9901 - val
Epoch 93/200
50000/50000 [==============================] - 7s 148us/step - loss: 0.0507 - acc: 0.9914 - val
Epoch 94/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0535 - acc: 0.9911 - val
Epoch 95/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0526 - acc: 0.9913 - val
Epoch 96/200
50000/50000 [==============================] - 7s 148us/step - loss: 0.0622 - acc: 0.9907 - val
Epoch 97/200
50000/50000 [==============================] - 7s 138us/step - loss: 0.0543 - acc: 0.9909 - val
Epoch 98/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0625 - acc: 0.9906 - val
Epoch 99/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0573 - acc: 0.9911 - val
Epoch 100/200
```

```
50000/50000 [==============================] - 7s 133us/step - loss: 0.0634 - acc: 0.9909 - val
Epoch 101/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0578 - acc: 0.9913 - val
Epoch 102/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0574 - acc: 0.9915 - val
Epoch 103/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0550 - acc: 0.9915 - val
Epoch 104/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0559 - acc: 0.9907 - val
Epoch 105/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0586 - acc: 0.9912 - val
Epoch 106/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0522 - acc: 0.9917 - val
Epoch 107/200
50000/50000 [==============================] - 7s 130us/step - loss: 0.0533 - acc: 0.9917 - val
Epoch 108/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0591 - acc: 0.9919 - val
Epoch 109/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0645 - acc: 0.9913 - val
Epoch 110/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0627 - acc: 0.9914 - val
Epoch 111/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0605 - acc: 0.9908 - val
Epoch 112/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0577 - acc: 0.9912 - val
Epoch 113/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0687 - acc: 0.9910 - val
Epoch 114/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0635 - acc: 0.9913 - val
Epoch 115/200
50000/50000 [==============================] - 7s 137us/step - loss: 0.0622 - acc: 0.9910 - val
Epoch 116/200
50000/50000 [==============================] - 7s 146us/step - loss: 0.0649 - acc: 0.9905 - val
Epoch 117/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0668 - acc: 0.9905 - val
Epoch 118/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0561 - acc: 0.9913 - val
Epoch 119/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0571 - acc: 0.9917 - val
Epoch 120/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0639 - acc: 0.9916 - val
Epoch 121/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0554 - acc: 0.9918 - val
Epoch 122/200
50000/50000 [==============================] - 7s 139us/step - loss: 0.0646 - acc: 0.9915 - val
Epoch 123/200
50000/50000 [==============================] - 7s 139us/step - loss: 0.0680 - acc: 0.9909 - val
Epoch 124/200
```

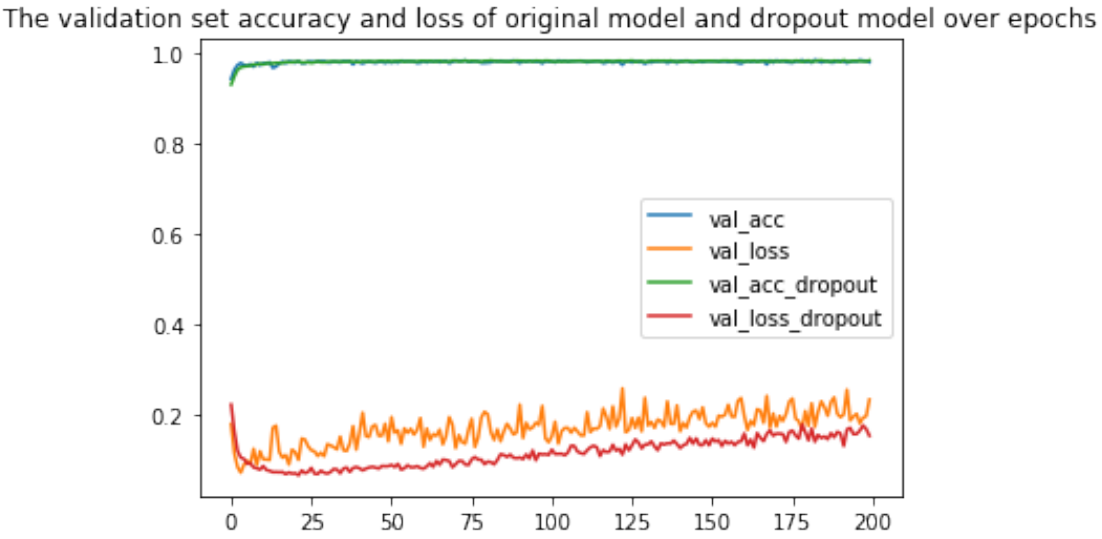
```
50000/50000 [==============================] - 7s 132us/step - loss: 0.0559 - acc: 0.9923 - val
Epoch 125/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0631 - acc: 0.9912 - val
Epoch 126/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0630 - acc: 0.9919 - val
Epoch 127/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0607 - acc: 0.9919 - val
Epoch 128/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0673 - acc: 0.9909 - val
Epoch 129/200
50000/50000 [==============================] - 8s 155us/step - loss: 0.0646 - acc: 0.9913 - val
Epoch 130/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.0632 - acc: 0.9910 - val
Epoch 131/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0643 - acc: 0.9909 - val
Epoch 132/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0685 - acc: 0.9910 - val
Epoch 133/200
50000/50000 [==============================] - 7s 138us/step - loss: 0.0704 - acc: 0.9908 - val
Epoch 134/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0715 - acc: 0.9908 - val
Epoch 135/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0682 - acc: 0.9909 - val
Epoch 136/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0677 - acc: 0.9914 - val
Epoch 137/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0675 - acc: 0.9915 - val
Epoch 138/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0640 - acc: 0.9917 - val
Epoch 139/200
50000/50000 [==============================] - 7s 138us/step - loss: 0.0650 - acc: 0.9919 - val
Epoch 140/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0713 - acc: 0.9910 - val
Epoch 141/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0699 - acc: 0.9909 - val
Epoch 142/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0708 - acc: 0.9909 - val
Epoch 143/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0677 - acc: 0.9913 - val
Epoch 144/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0743 - acc: 0.9908 - val
Epoch 145/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.0739 - acc: 0.9909 - val
Epoch 146/200
50000/50000 [==============================] - 7s 138us/step - loss: 0.0676 - acc: 0.9915 - val
Epoch 147/200
50000/50000 [==============================] - 7s 138us/step - loss: 0.0720 - acc: 0.9907 - val
Epoch 148/200
```

```
50000/50000 [==============================] - 7s 136us/step - loss: 0.0736 - acc: 0.9911 - val
Epoch 149/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0681 - acc: 0.9914 - val
Epoch 150/200
50000/50000 [==============================] - 7s 139us/step - loss: 0.0698 - acc: 0.9913 - val
Epoch 151/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0722 - acc: 0.9909 - val
Epoch 152/200
50000/50000 [==============================] - 7s 133us/step - loss: 0.0790 - acc: 0.9904 - val
Epoch 153/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0681 - acc: 0.9912 - val
Epoch 154/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0737 - acc: 0.9911 - val
Epoch 155/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0715 - acc: 0.9911 - val
Epoch 156/200
50000/50000 [==============================] - 6s 110us/step - loss: 0.0826 - acc: 0.9901 - val
Epoch 157/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.0737 - acc: 0.9910 - val
Epoch 158/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.0717 - acc: 0.9908 - val
Epoch 159/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.0708 - acc: 0.9909 - val
Epoch 160/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0774 - acc: 0.9911 - val
Epoch 161/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.0788 - acc: 0.9908 - val
Epoch 162/200
50000/50000 [==============================] - 6s 128us/step - loss: 0.0753 - acc: 0.9909 - val
Epoch 163/200
50000/50000 [==============================] - 7s 147us/step - loss: 0.0731 - acc: 0.9912 - val
Epoch 164/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0830 - acc: 0.9905 - val
Epoch 165/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0672 - acc: 0.9922 - val
Epoch 166/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0831 - acc: 0.9909 - val
Epoch 167/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.0848 - acc: 0.9904 - val
Epoch 168/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0705 - acc: 0.9921 - val
Epoch 169/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.0832 - acc: 0.9909 - val
Epoch 170/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.0715 - acc: 0.9921 - val
Epoch 171/200
50000/50000 [==============================] - 6s 128us/step - loss: 0.0769 - acc: 0.9914 - val
Epoch 172/200
```

```
50000/50000 [==============================] - 7s 134us/step - loss: 0.0798 - acc: 0.9909 - val
Epoch 173/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0909 - acc: 0.9907 - val
Epoch 174/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0860 - acc: 0.9911 - val
Epoch 175/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0783 - acc: 0.9912 - val
Epoch 176/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.0905 - acc: 0.9907 - val
Epoch 177/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0803 - acc: 0.9914 - val
Epoch 178/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0811 - acc: 0.9910 - val
Epoch 179/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0799 - acc: 0.9912 - val
Epoch 180/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0899 - acc: 0.9902 - val
Epoch 181/200
50000/50000 [==============================] - 5s 109us/step - loss: 0.0849 - acc: 0.9908 - val
Epoch 182/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0822 - acc: 0.9907 - val
Epoch 183/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.0866 - acc: 0.9905 - val
Epoch 184/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.0783 - acc: 0.9914 - val
Epoch 185/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0905 - acc: 0.9905 - val
Epoch 186/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0804 - acc: 0.9910 - val
Epoch 187/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0883 - acc: 0.9906 - val
Epoch 188/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0828 - acc: 0.9908 - val
Epoch 189/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.0804 - acc: 0.9914 - val
Epoch 190/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0804 - acc: 0.9914 - val
Epoch 191/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0785 - acc: 0.9906 - val
Epoch 192/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.0826 - acc: 0.9910 - val
Epoch 193/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0848 - acc: 0.9910 - val
Epoch 194/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0776 - acc: 0.9920 - val
Epoch 195/200
50000/50000 [==============================] - 8s 152us/step - loss: 0.0873 - acc: 0.9914 - val
Epoch 196/200
```

```
50000/50000 [==============================] - 7s 148us/step - loss: 0.0859 - acc: 0.9911 - val
Epoch 197/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0853 - acc: 0.9908 - val
Epoch 198/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0869 - acc: 0.9912 - val
Epoch 199/200
50000/50000 [==============================] - 7s 147us/step - loss: 0.0793 - acc: 0.9919 - val
Epoch 200/200
50000/50000 [==============================] - 7s 142us/step - loss: 0.0827 - acc: 0.9917 - val
```

```
In [10]: val_acc = result_org.history['val_acc']
         val_loss = result_org.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()
```



This model perform slightly better compared with the old model in terms of val_loss, but the val_acc are really similar.

iii.Weight regularization

```
In [11]: 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.l1
network_l1.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l1
network_l1.add(layers.Dense(512, activation='relu', kernel_regularizer=regularizers.l1
network_l1.add(layers.Dense(10, activation='softmax'))
network_l1.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['acc
result_l1 = network_l1.fit(train_images, train_labels,validation_data=(valid_images,va
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 6s 119us/step - loss: 13.7783 - acc: 0.6669 - va
Epoch 2/200
50000/50000 [==============================] - 6s 113us/step - loss: 3.0588 - acc: 0.7929 - val
Epoch 3/200
50000/50000 [==============================] - 6s 118us/step - loss: 2.1836 - acc: 0.8357 - val
Epoch 4/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.8568 - acc: 0.8606 - val
Epoch 5/200
50000/50000 [==============================] - 6s 115us/step - loss: 1.6821 - acc: 0.8743 - val
Epoch 6/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.5538 - acc: 0.8866 - val
Epoch 7/200
50000/50000 [==============================] - 6s 114us/step - loss: 1.4701 - acc: 0.8955 - val
Epoch 8/200
50000/50000 [==============================] - 5s 104us/step - loss: 1.3969 - acc: 0.9050 - val
Epoch 9/200
50000/50000 [==============================] - 6s 113us/step - loss: 1.3473 - acc: 0.9121 - val
Epoch 10/200
50000/50000 [==============================] - 7s 138us/step - loss: 1.3055 - acc: 0.9176 - val
Epoch 11/200
50000/50000 [==============================] - 5s 109us/step - loss: 1.2727 - acc: 0.9221 - val
Epoch 12/200
50000/50000 [==============================] - 6s 116us/step - loss: 1.2387 - acc: 0.9264 - val
Epoch 13/200
50000/50000 [==============================] - 6s 119us/step - loss: 1.2090 - acc: 0.9301 - val
Epoch 14/200
50000/50000 [==============================] - 6s 112us/step - loss: 1.1832 - acc: 0.9321 - val
Epoch 15/200
50000/50000 [==============================] - 7s 137us/step - loss: 1.1615 - acc: 0.9348 - val
Epoch 16/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.1450 - acc: 0.9354 - val
Epoch 17/200
50000/50000 [==============================] - 5s 109us/step - loss: 1.1303 - acc: 0.9366 - val
Epoch 18/200
50000/50000 [==============================] - 6s 114us/step - loss: 1.1182 - acc: 0.9381 - val
Epoch 19/200
50000/50000 [==============================] - 7s 138us/step - loss: 1.1057 - acc: 0.9397 - val
Epoch 20/200
50000/50000 [==============================] - 6s 129us/step - loss: 1.0981 - acc: 0.9402 - val
```

```
Epoch 21/200
50000/50000 [==============================] - 6s 119us/step - loss: 1.0851 - acc: 0.9421 - val
Epoch 22/200
50000/50000 [==============================] - 6s 119us/step - loss: 1.0784 - acc: 0.9416 - val
Epoch 23/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.0691 - acc: 0.9430 - val
Epoch 24/200
50000/50000 [==============================] - 6s 119us/step - loss: 1.0607 - acc: 0.9443 - val
Epoch 25/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.0518 - acc: 0.9459 - val
Epoch 26/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.0451 - acc: 0.9463 - val
Epoch 27/200
50000/50000 [==============================] - 6s 119us/step - loss: 1.0388 - acc: 0.9460 - val
Epoch 28/200
50000/50000 [==============================] - 6s 124us/step - loss: 1.0341 - acc: 0.9462 - val
Epoch 29/200
50000/50000 [==============================] - 6s 123us/step - loss: 1.0289 - acc: 0.9459 - val
Epoch 30/200
50000/50000 [==============================] - 6s 117us/step - loss: 1.0237 - acc: 0.9478 - val
Epoch 31/200
50000/50000 [==============================] - 6s 117us/step - loss: 1.0187 - acc: 0.9480 - val
Epoch 32/200
50000/50000 [==============================] - 6s 117us/step - loss: 1.0130 - acc: 0.9500 - val
Epoch 33/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.0096 - acc: 0.9493 - val
Epoch 34/200
50000/50000 [==============================] - 6s 117us/step - loss: 1.0073 - acc: 0.9491 - val
Epoch 35/200
50000/50000 [==============================] - 6s 118us/step - loss: 1.0030 - acc: 0.9494 - val
Epoch 36/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.9991 - acc: 0.9493 - val
Epoch 37/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9952 - acc: 0.9509 - val
Epoch 38/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9943 - acc: 0.9497 - val
Epoch 39/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9891 - acc: 0.9506 - val
Epoch 40/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9870 - acc: 0.9507 - val
Epoch 41/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9879 - acc: 0.9499 - val
Epoch 42/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9823 - acc: 0.9521 - val
Epoch 43/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9805 - acc: 0.9510 - val
Epoch 44/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.9772 - acc: 0.9524 - val
```

```
Epoch 45/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.9732 - acc: 0.9527 - val
Epoch 46/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9741 - acc: 0.9516 - val
Epoch 47/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9726 - acc: 0.9518 - val
Epoch 48/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9691 - acc: 0.9535 - val
Epoch 49/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9638 - acc: 0.9541 - val
Epoch 50/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.9664 - acc: 0.9524 - val
Epoch 51/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.9652 - acc: 0.9530 - val
Epoch 52/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.9617 - acc: 0.9534 - val
Epoch 53/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.9584 - acc: 0.9543 - val
Epoch 54/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.9587 - acc: 0.9539 - val
Epoch 55/200
50000/50000 [==============================] - 5s 105us/step - loss: 0.9581 - acc: 0.9540 - val
Epoch 56/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9546 - acc: 0.9550 - val
Epoch 57/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9530 - acc: 0.9547 - val
Epoch 58/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9519 - acc: 0.9546 - val
Epoch 59/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9502 - acc: 0.9546 - val
Epoch 60/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9502 - acc: 0.9543 - val
Epoch 61/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9483 - acc: 0.9550 - val
Epoch 62/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9486 - acc: 0.9540 - val
Epoch 63/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.9461 - acc: 0.9555 - val
Epoch 64/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9436 - acc: 0.9558 - val
Epoch 65/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.9471 - acc: 0.9539 - val
Epoch 66/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9430 - acc: 0.9561 - val
Epoch 67/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9392 - acc: 0.9560 - val
Epoch 68/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9401 - acc: 0.9568 - val
```

```
Epoch 69/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9392 - acc: 0.9557 - val
Epoch 70/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9400 - acc: 0.9556 - val
Epoch 71/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9346 - acc: 0.9569 - val
Epoch 72/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.9362 - acc: 0.9568 - val
Epoch 73/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9342 - acc: 0.9562 - val
Epoch 74/200
50000/50000 [==============================] - 5s 105us/step - loss: 0.9344 - acc: 0.9563 - val
Epoch 75/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9348 - acc: 0.9566 - val
Epoch 76/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.9322 - acc: 0.9567 - val
Epoch 77/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.9297 - acc: 0.9567 - val
Epoch 78/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.9296 - acc: 0.9571 - val
Epoch 79/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9299 - acc: 0.9568 - val
Epoch 80/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9308 - acc: 0.9560 - val
Epoch 81/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9262 - acc: 0.9575 - val
Epoch 82/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.9261 - acc: 0.9571 - val
Epoch 83/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.9267 - acc: 0.9576 - val
Epoch 84/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.9227 - acc: 0.9576 - val
Epoch 85/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9240 - acc: 0.9577 - val
Epoch 86/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9236 - acc: 0.9576 - val
Epoch 87/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9220 - acc: 0.9581 - val
Epoch 88/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9248 - acc: 0.9572 - val
Epoch 89/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.9187 - acc: 0.9588 - val
Epoch 90/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9189 - acc: 0.9583 - val
Epoch 91/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9185 - acc: 0.9586 - val
Epoch 92/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9189 - acc: 0.9583 - val
```

```
Epoch 93/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9199 - acc: 0.9582 - val
Epoch 94/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.9177 - acc: 0.9584 - val
Epoch 95/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.9136 - acc: 0.9592 - val
Epoch 96/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9146 - acc: 0.9591 - val
Epoch 97/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9151 - acc: 0.9580 - val
Epoch 98/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9168 - acc: 0.9569 - val
Epoch 99/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9144 - acc: 0.9584 - val
Epoch 100/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9119 - acc: 0.9574 - val
Epoch 101/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.9141 - acc: 0.9584 - val
Epoch 102/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9121 - acc: 0.9593 - val
Epoch 103/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9105 - acc: 0.9594 - val
Epoch 104/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.9092 - acc: 0.9598 - val
Epoch 105/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.9088 - acc: 0.9596 - val
Epoch 106/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.9106 - acc: 0.9585 - val
Epoch 107/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.9090 - acc: 0.9583 - val
Epoch 108/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.9066 - acc: 0.9588 - val
Epoch 109/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9065 - acc: 0.9589 - val
Epoch 110/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9061 - acc: 0.9589 - val
Epoch 111/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.9039 - acc: 0.9597 - val
Epoch 112/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.9051 - acc: 0.9592 - val
Epoch 113/200
50000/50000 [==============================] - 6s 125us/step - loss: 0.9013 - acc: 0.9599 - val
Epoch 114/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.9014 - acc: 0.9604 - val
Epoch 115/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.9010 - acc: 0.9604 - val
Epoch 116/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.9015 - acc: 0.9601 - val
```

```
Epoch 117/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9029 - acc: 0.9588 - val
Epoch 118/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.9009 - acc: 0.9596 - val
Epoch 119/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8986 - acc: 0.9602 - val
Epoch 120/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8989 - acc: 0.9595 - val
Epoch 121/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.8992 - acc: 0.9595 - val
Epoch 122/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8970 - acc: 0.9603 - val
Epoch 123/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.8987 - acc: 0.9590 - val
Epoch 124/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.8932 - acc: 0.9619 - val
Epoch 125/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.8975 - acc: 0.9588 - val
Epoch 126/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8946 - acc: 0.9596 - val
Epoch 127/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.8944 - acc: 0.9594 - val
Epoch 128/200
50000/50000 [==============================] - 7s 141us/step - loss: 0.8940 - acc: 0.9601 - val
Epoch 129/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.8920 - acc: 0.9600 - val
Epoch 130/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8916 - acc: 0.9609 - val
Epoch 131/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.8949 - acc: 0.9586 - val
Epoch 132/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8908 - acc: 0.9612 - val
Epoch 133/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.8922 - acc: 0.9601 - val
Epoch 134/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.8893 - acc: 0.9615 - val
Epoch 135/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.8895 - acc: 0.9619 - val
Epoch 136/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.8889 - acc: 0.9604 - val
Epoch 137/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.8886 - acc: 0.9605 - val
Epoch 138/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.8888 - acc: 0.9610 - val
Epoch 139/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.8888 - acc: 0.9612 - val
Epoch 140/200
50000/50000 [==============================] - 7s 130us/step - loss: 0.8887 - acc: 0.9618 - val
```

```
Epoch 141/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8875 - acc: 0.9608 - val
Epoch 142/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.8877 - acc: 0.9602 - val
Epoch 143/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.8857 - acc: 0.9608 - val
Epoch 144/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.8874 - acc: 0.9607 - val
Epoch 145/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.8864 - acc: 0.9618 - val
Epoch 146/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8839 - acc: 0.9622 - val
Epoch 147/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.8825 - acc: 0.9621 - val
Epoch 148/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8851 - acc: 0.9609 - val
Epoch 149/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.8847 - acc: 0.9613 - val
Epoch 150/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.8837 - acc: 0.9617 - val
Epoch 151/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.8856 - acc: 0.9604 - val
Epoch 152/200
50000/50000 [==============================] - 6s 112us/step - loss: 0.8829 - acc: 0.9616 - val
Epoch 153/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.8829 - acc: 0.9614 - val
Epoch 154/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8873 - acc: 0.9603 - val
Epoch 155/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.8782 - acc: 0.9631 - val
Epoch 156/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.8837 - acc: 0.9611 - val
Epoch 157/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.8812 - acc: 0.9607 - val
Epoch 158/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.8798 - acc: 0.9622 - val
Epoch 159/200
50000/50000 [==============================] - 6s 113us/step - loss: 0.8818 - acc: 0.9602 - val
Epoch 160/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.8793 - acc: 0.9617 - val
Epoch 161/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.8791 - acc: 0.9615 - val
Epoch 162/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8792 - acc: 0.9617 - val
Epoch 163/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.8783 - acc: 0.9617 - val
Epoch 164/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8789 - acc: 0.9614 - val
```

```
Epoch 165/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.8786 - acc: 0.9614 - val
Epoch 166/200
50000/50000 [==============================] - 5s 107us/step - loss: 0.8828 - acc: 0.9603 - val
Epoch 167/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.8739 - acc: 0.9633 - val
Epoch 168/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.8795 - acc: 0.9617 - val
Epoch 169/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8772 - acc: 0.9620 - val
Epoch 170/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.8804 - acc: 0.9608 - val
Epoch 171/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8765 - acc: 0.9622 - val
Epoch 172/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8782 - acc: 0.9613 - val
Epoch 173/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.8749 - acc: 0.9615 - val
Epoch 174/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.8746 - acc: 0.9618 - val
Epoch 175/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.8764 - acc: 0.9613 - val
Epoch 176/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.8796 - acc: 0.9605 - val
Epoch 177/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8733 - acc: 0.9622 - val
Epoch 178/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8737 - acc: 0.9630 - val
Epoch 179/200
50000/50000 [==============================] - 5s 103us/step - loss: 0.8748 - acc: 0.9622 - val
Epoch 180/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8730 - acc: 0.9622 - val
Epoch 181/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8751 - acc: 0.9620 - val
Epoch 182/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.8781 - acc: 0.9601 - val
Epoch 183/200
50000/50000 [==============================] - 7s 140us/step - loss: 0.8715 - acc: 0.9621 - val
Epoch 184/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.8712 - acc: 0.9622 - val
Epoch 185/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8732 - acc: 0.9626 - val
Epoch 186/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8746 - acc: 0.9615 - val
Epoch 187/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.8749 - acc: 0.9616 - val
Epoch 188/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8723 - acc: 0.9626 - val
```

```
Epoch 189/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8719 - acc: 0.9624 - val
Epoch 190/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.8705 - acc: 0.9619 - val
Epoch 191/200
50000/50000 [==============================] - 6s 126us/step - loss: 0.8741 - acc: 0.9618 - val
Epoch 192/200
50000/50000 [==============================] - 5s 110us/step - loss: 0.8703 - acc: 0.9634 - val
Epoch 193/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.8720 - acc: 0.9625 - val
Epoch 194/200
50000/50000 [==============================] - 5s 108us/step - loss: 0.8716 - acc: 0.9621 - val
Epoch 195/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.8701 - acc: 0.9625 - val
Epoch 196/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8701 - acc: 0.9622 - val
Epoch 197/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.8727 - acc: 0.9619 - val
Epoch 198/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.8700 - acc: 0.9624 - val
Epoch 199/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.8691 - acc: 0.9624 - val
Epoch 200/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.8696 - acc: 0.9620 - val
```

```
In [12]: 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(train_images, train_labels,validation_data=(valid_images,va
```

```
Train on 50000 samples, validate on 10000 samples
Epoch 1/200
50000/50000 [==============================] - 7s 137us/step - loss: 1.8150 - acc: 0.8194 - val
Epoch 2/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.8292 - acc: 0.9371 - val
Epoch 3/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.5360 - acc: 0.9513 - val
Epoch 4/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.3975 - acc: 0.9602 - val
Epoch 5/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.3308 - acc: 0.9648 - val
Epoch 6/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.2892 - acc: 0.9676 - val
```

```
Epoch 7/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.2532 - acc: 0.9729 - val
Epoch 8/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.2411 - acc: 0.9717 - val
Epoch 9/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.2165 - acc: 0.9753 - val
Epoch 10/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.2089 - acc: 0.9757 - val
Epoch 11/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.1945 - acc: 0.9784 - val
Epoch 12/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.1850 - acc: 0.9797 - val
Epoch 13/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1831 - acc: 0.9785 - val
Epoch 14/200
50000/50000 [==============================] - 6s 125us/step - loss: 0.1692 - acc: 0.9817 - val
Epoch 15/200
50000/50000 [==============================] - 6s 128us/step - loss: 0.1668 - acc: 0.9821 - val
Epoch 16/200
50000/50000 [==============================] - 7s 131us/step - loss: 0.1583 - acc: 0.9832 - val
Epoch 17/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.1570 - acc: 0.9825 - val
Epoch 18/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.1523 - acc: 0.9832 - val
Epoch 19/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.1464 - acc: 0.9841 - val
Epoch 20/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1437 - acc: 0.9840 - val
Epoch 21/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1418 - acc: 0.9842 - val
Epoch 22/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1357 - acc: 0.9852 - val
Epoch 23/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1340 - acc: 0.9864 - val
Epoch 24/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1331 - acc: 0.9853 - val
Epoch 25/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1304 - acc: 0.9863 - val
Epoch 26/200
50000/50000 [==============================] - 7s 136us/step - loss: 0.1286 - acc: 0.9860 - val
Epoch 27/200
50000/50000 [==============================] - 6s 126us/step - loss: 0.1261 - acc: 0.9867 - val
Epoch 28/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1247 - acc: 0.9866 - val
Epoch 29/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1237 - acc: 0.9868 - val
Epoch 30/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1181 - acc: 0.9885 - val
```

```
Epoch 31/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1211 - acc: 0.9867 - val
Epoch 32/200
50000/50000 [==============================] - 6s 125us/step - loss: 0.1180 - acc: 0.9880 - val
Epoch 33/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1171 - acc: 0.9881 - val
Epoch 34/200
50000/50000 [==============================] - 6s 129us/step - loss: 0.1154 - acc: 0.9884 - val
Epoch 35/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.1132 - acc: 0.9885 - val
Epoch 36/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.1137 - acc: 0.9881 - val
Epoch 37/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1120 - acc: 0.9889 - val
Epoch 38/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1120 - acc: 0.9881 - val
Epoch 39/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.1075 - acc: 0.9894 - val
Epoch 40/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.1098 - acc: 0.9885 - val
Epoch 41/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.1111 - acc: 0.9885 - val
Epoch 42/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.1058 - acc: 0.9899 - val
Epoch 43/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1086 - acc: 0.9887 - val
Epoch 44/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.1050 - acc: 0.9894 - val
Epoch 45/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1017 - acc: 0.9901 - val
Epoch 46/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1036 - acc: 0.9897 - val
Epoch 47/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1030 - acc: 0.9896 - val
Epoch 48/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.1055 - acc: 0.9890 - val
Epoch 49/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0983 - acc: 0.9911 - val
Epoch 50/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.1020 - acc: 0.9895 - val
Epoch 51/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.1004 - acc: 0.9904 - val
Epoch 52/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.0984 - acc: 0.9907 - val
Epoch 53/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.1025 - acc: 0.9890 - val
Epoch 54/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0998 - acc: 0.9896 - val
```

```
Epoch 55/200
50000/50000 [==============================] - 6s 115us/step - loss: 0.0985 - acc: 0.9901 - val
Epoch 56/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0963 - acc: 0.9909 - val
Epoch 57/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0965 - acc: 0.9906 - val
Epoch 58/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0978 - acc: 0.9906 - val
Epoch 59/200
50000/50000 [==============================] - 6s 117us/step - loss: 0.0967 - acc: 0.9900 - val
Epoch 60/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0980 - acc: 0.9900 - val
Epoch 61/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0945 - acc: 0.9910 - val
Epoch 62/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0969 - acc: 0.9901 - val
Epoch 63/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0952 - acc: 0.9908 - val
Epoch 64/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0956 - acc: 0.9906 - val
Epoch 65/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0979 - acc: 0.9900 - val
Epoch 66/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0895 - acc: 0.9920 - val
Epoch 67/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0974 - acc: 0.9890 - val
Epoch 68/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0918 - acc: 0.9915 - val
Epoch 69/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0927 - acc: 0.9908 - val
Epoch 70/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0919 - acc: 0.9911 - val
Epoch 71/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0939 - acc: 0.9907 - val
Epoch 72/200
50000/50000 [==============================] - 5s 106us/step - loss: 0.0953 - acc: 0.9901 - val
Epoch 73/200
50000/50000 [==============================] - 6s 126us/step - loss: 0.0898 - acc: 0.9913 - val
Epoch 74/200
50000/50000 [==============================] - 5s 105us/step - loss: 0.0912 - acc: 0.9909 - val
Epoch 75/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0945 - acc: 0.9898 - val
Epoch 76/200
50000/50000 [==============================] - 6s 130us/step - loss: 0.0886 - acc: 0.9914 - val
Epoch 77/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0932 - acc: 0.9906 - val
Epoch 78/200
50000/50000 [==============================] - 6s 126us/step - loss: 0.0904 - acc: 0.9912 - val
```

```
Epoch 79/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0895 - acc: 0.9909 - val
Epoch 80/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0877 - acc: 0.9920 - val
Epoch 81/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0928 - acc: 0.9902 - val
Epoch 82/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0880 - acc: 0.9918 - val
Epoch 83/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0870 - acc: 0.9918 - val
Epoch 84/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0912 - acc: 0.9904 - val_
Epoch 85/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0891 - acc: 0.9911 - val
Epoch 86/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0917 - acc: 0.9910 - val
Epoch 87/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0886 - acc: 0.9910 - val
Epoch 88/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0892 - acc: 0.9909 - val
Epoch 89/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0876 - acc: 0.9915 - val
Epoch 90/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0870 - acc: 0.9914 - val
Epoch 91/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0862 - acc: 0.9921 - val
Epoch 92/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0873 - acc: 0.9915 - val
Epoch 93/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0880 - acc: 0.9913 - val
Epoch 94/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0869 - acc: 0.9912 - val
Epoch 95/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0861 - acc: 0.9918 - val
Epoch 96/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0916 - acc: 0.9906 - val
Epoch 97/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0843 - acc: 0.9922 - val
Epoch 98/200
50000/50000 [==============================] - 5s 99us/step - loss: 0.0866 - acc: 0.9913 - val_
Epoch 99/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0882 - acc: 0.9905 - val
Epoch 100/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0839 - acc: 0.9920 - val
Epoch 101/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0870 - acc: 0.9913 - val
Epoch 102/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0841 - acc: 0.9923 - val
```

```
Epoch 103/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0853 - acc: 0.9920 - val
Epoch 104/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0852 - acc: 0.9921 - val
Epoch 105/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0855 - acc: 0.9917 - val
Epoch 106/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0854 - acc: 0.9916 - val
Epoch 107/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0834 - acc: 0.9925 - val
Epoch 108/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0848 - acc: 0.9920 - val
Epoch 109/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.0842 - acc: 0.9915 - val
Epoch 110/200
50000/50000 [==============================] - 6s 118us/step - loss: 0.0838 - acc: 0.9916 - val
Epoch 111/200
50000/50000 [==============================] - 6s 119us/step - loss: 0.0845 - acc: 0.9914 - val
Epoch 112/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0837 - acc: 0.9920 - val
Epoch 113/200
50000/50000 [==============================] - 6s 116us/step - loss: 0.0848 - acc: 0.9914 - val
Epoch 114/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0874 - acc: 0.9911 - val
Epoch 115/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0862 - acc: 0.9910 - val
Epoch 116/200
50000/50000 [==============================] - 6s 125us/step - loss: 0.0813 - acc: 0.9924 - val
Epoch 117/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0802 - acc: 0.9927 - val
Epoch 118/200
50000/50000 [==============================] - 6s 114us/step - loss: 0.0854 - acc: 0.9911 - val
Epoch 119/200
50000/50000 [==============================] - 5s 102us/step - loss: 0.0829 - acc: 0.9918 - val
Epoch 120/200
50000/50000 [==============================] - 5s 100us/step - loss: 0.0805 - acc: 0.9927 - val
Epoch 121/200
50000/50000 [==============================] - 5s 104us/step - loss: 0.0834 - acc: 0.9917 - val
Epoch 122/200
50000/50000 [==============================] - 5s 101us/step - loss: 0.0829 - acc: 0.9917 - val
Epoch 123/200
50000/50000 [==============================] - 8s 156us/step - loss: 0.0833 - acc: 0.9915 - val
Epoch 124/200
50000/50000 [==============================] - 9s 175us/step - loss: 0.0816 - acc: 0.9918 - val
Epoch 125/200
50000/50000 [==============================] - 8s 170us/step - loss: 0.0795 - acc: 0.9927 - val
Epoch 126/200
50000/50000 [==============================] - 8s 169us/step - loss: 0.0830 - acc: 0.9911 - val
```

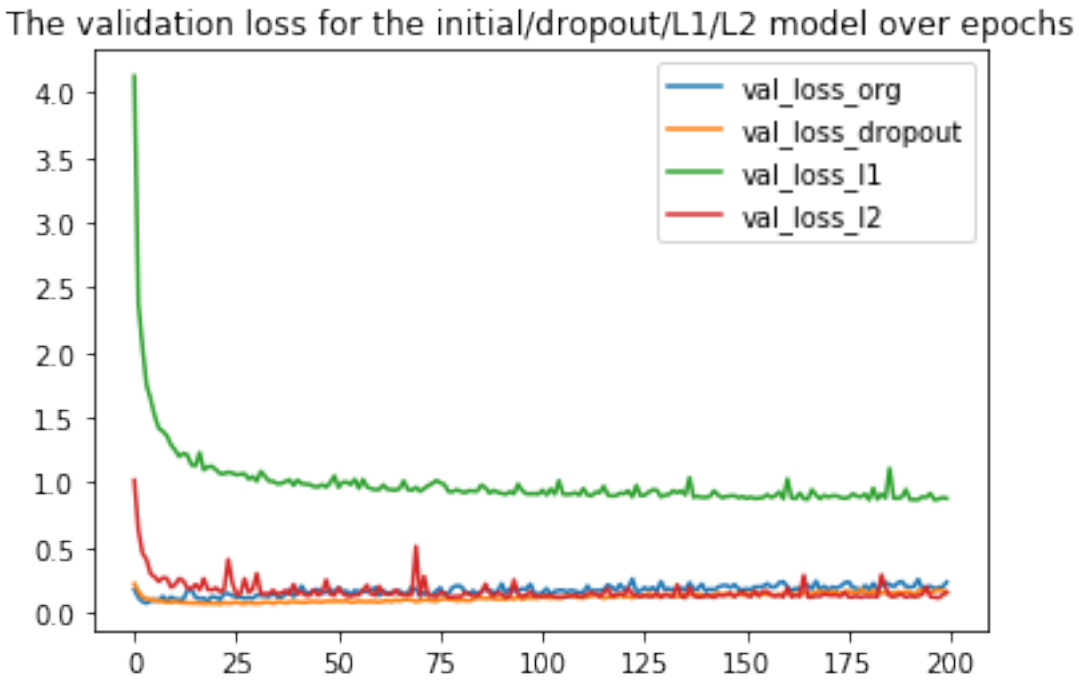
```
Epoch 127/200
50000/50000 [==============================] - 8s 168us/step - loss: 0.0809 - acc: 0.9926 - val
Epoch 128/200
50000/50000 [==============================] - 8s 165us/step - loss: 0.0805 - acc: 0.9921 - val
Epoch 129/200
50000/50000 [==============================] - 9s 170us/step - loss: 0.0852 - acc: 0.9906 - val
Epoch 130/200
50000/50000 [==============================] - 8s 169us/step - loss: 0.0813 - acc: 0.9920 - val
Epoch 131/200
50000/50000 [==============================] - 6s 111us/step - loss: 0.0799 - acc: 0.9925 - val
Epoch 132/200
50000/50000 [==============================] - 7s 135us/step - loss: 0.0807 - acc: 0.9915 - val
Epoch 133/200
50000/50000 [==============================] - 7s 134us/step - loss: 0.0787 - acc: 0.9926 - val
Epoch 134/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0821 - acc: 0.9923 - val
Epoch 135/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0794 - acc: 0.9922 - val
Epoch 136/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0876 - acc: 0.9899 - val
Epoch 137/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.0794 - acc: 0.9925 - val
Epoch 138/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0796 - acc: 0.9926 - val
Epoch 139/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0789 - acc: 0.9931 - val
Epoch 140/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0790 - acc: 0.9925 - val
Epoch 141/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0806 - acc: 0.9917 - val
Epoch 142/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0774 - acc: 0.9928 - val
Epoch 143/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0806 - acc: 0.9919 - val
Epoch 144/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0780 - acc: 0.9923 - val
Epoch 145/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0783 - acc: 0.9923 - val
Epoch 146/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0785 - acc: 0.9923 - val
Epoch 147/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0783 - acc: 0.9925 - val
Epoch 148/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0781 - acc: 0.9925 - val
Epoch 149/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0796 - acc: 0.9922 - val
Epoch 150/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0797 - acc: 0.9921 - val
```

```
Epoch 151/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0782 - acc: 0.9927 - val
Epoch 152/200
50000/50000 [==============================] - 6s 120us/step - loss: 0.0775 - acc: 0.9927 - val
Epoch 153/200
50000/50000 [==============================] - 6s 124us/step - loss: 0.0791 - acc: 0.9923 - val
Epoch 154/200
50000/50000 [==============================] - 6s 123us/step - loss: 0.0800 - acc: 0.9918 - val
Epoch 155/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0784 - acc: 0.9920 - val
Epoch 156/200
50000/50000 [==============================] - 6s 122us/step - loss: 0.0793 - acc: 0.9919 - val
Epoch 157/200
50000/50000 [==============================] - 6s 121us/step - loss: 0.0767 - acc: 0.9926 - val
Epoch 158/200
50000/50000 [==============================] - 6s 127us/step - loss: 0.0782 - acc: 0.9920 - val
Epoch 159/200
50000/50000 [==============================] - 6s 125us/step - loss: 0.0771 - acc: 0.9926 - val
Epoch 160/200
50000/50000 [==============================] - 6s 126us/step - loss: 0.0796 - acc: 0.9923 - val
Epoch 161/200
50000/50000 [==============================] - 8s 164us/step - loss: 0.0777 - acc: 0.9926 - val
Epoch 162/200
50000/50000 [==============================] - 9s 180us/step - loss: 0.0791 - acc: 0.9919 - val
Epoch 163/200
50000/50000 [==============================] - 9s 180us/step - loss: 0.0767 - acc: 0.9925 - val
Epoch 164/200
50000/50000 [==============================] - 9s 174us/step - loss: 0.0755 - acc: 0.9932 - val
Epoch 165/200
50000/50000 [==============================] - 9s 185us/step - loss: 0.0778 - acc: 0.9922 - val
Epoch 166/200
50000/50000 [==============================] - 9s 178us/step - loss: 0.0776 - acc: 0.9928 - val
Epoch 167/200
50000/50000 [==============================] - 9s 172us/step - loss: 0.0774 - acc: 0.9926 - val
Epoch 168/200
50000/50000 [==============================] - 9s 179us/step - loss: 0.0788 - acc: 0.9923 - val
Epoch 169/200
50000/50000 [==============================] - 9s 178us/step - loss: 0.0785 - acc: 0.9922 - val
Epoch 170/200
50000/50000 [==============================] - 9s 175us/step - loss: 0.0784 - acc: 0.9918 - val
Epoch 171/200
50000/50000 [==============================] - 9s 170us/step - loss: 0.0767 - acc: 0.9927 - val
Epoch 172/200
50000/50000 [==============================] - 9s 173us/step - loss: 0.0772 - acc: 0.9924 - val
Epoch 173/200
50000/50000 [==============================] - 9s 172us/step - loss: 0.0769 - acc: 0.9923 - val
Epoch 174/200
50000/50000 [==============================] - 9s 172us/step - loss: 0.0758 - acc: 0.9928 - val
```

```
Epoch 175/200
50000/50000 [==============================] - 9s 171us/step - loss: 0.0759 - acc: 0.9928 - val
Epoch 176/200
50000/50000 [==============================] - 9s 172us/step - loss: 0.0794 - acc: 0.9917 - val
Epoch 177/200
50000/50000 [==============================] - 9s 175us/step - loss: 0.0739 - acc: 0.9931 - val
Epoch 178/200
50000/50000 [==============================] - 9s 177us/step - loss: 0.0773 - acc: 0.9922 - val
Epoch 179/200
50000/50000 [==============================] - 9s 172us/step - loss: 0.0770 - acc: 0.9924 - val
Epoch 180/200
50000/50000 [==============================] - 8s 170us/step - loss: 0.0773 - acc: 0.9926 - val
Epoch 181/200
50000/50000 [==============================] - 9s 171us/step - loss: 0.0758 - acc: 0.9926 - val
Epoch 182/200
50000/50000 [==============================] - 9s 171us/step - loss: 0.0775 - acc: 0.9924 - val
Epoch 183/200
50000/50000 [==============================] - 8s 153us/step - loss: 0.0834 - acc: 0.9905 - val
Epoch 184/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0728 - acc: 0.9935 - val
Epoch 185/200
50000/50000 [==============================] - 7s 132us/step - loss: 0.0750 - acc: 0.9932 - val
Epoch 186/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0757 - acc: 0.9928 - val
Epoch 187/200
50000/50000 [==============================] - 9s 174us/step - loss: 0.0767 - acc: 0.9923 - val
Epoch 188/200
50000/50000 [==============================] - 8s 169us/step - loss: 0.0774 - acc: 0.9923 - val
Epoch 189/200
50000/50000 [==============================] - 8s 169us/step - loss: 0.0761 - acc: 0.9927 - val
Epoch 190/200
50000/50000 [==============================] - 9s 174us/step - loss: 0.0768 - acc: 0.9923 - val
Epoch 191/200
50000/50000 [==============================] - 7s 148us/step - loss: 0.0787 - acc: 0.9918 - val
Epoch 192/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0744 - acc: 0.9931 - val
Epoch 193/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0764 - acc: 0.9924 - val
Epoch 194/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0740 - acc: 0.9936 - val
Epoch 195/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0799 - acc: 0.9911 - val
Epoch 196/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0752 - acc: 0.9923 - val
Epoch 197/200
50000/50000 [==============================] - 7s 145us/step - loss: 0.0798 - acc: 0.9917 - val
Epoch 198/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0758 - acc: 0.9928 - val
```

```
Epoch 199/200
50000/50000 [==============================] - 7s 143us/step - loss: 0.0747 - acc: 0.9929 - val
Epoch 200/200
50000/50000 [==============================] - 7s 144us/step - loss: 0.0746 - acc: 0.9928 - val
```

```
In [13]: val_loss_org = result_org.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_org)
         plt.plot(val_loss_dropout)
         plt.plot(val_loss_l1)
         plt.plot(val_loss_l2)
         plt.legend(['val_loss_org', '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()
```



The dropout-adding model appears to perform the best when the epoch number is smaller than 100, and the l2-loss model appears to perform the best when the epoch number is greater than 100.

iv. Final model

```
In [14]: network_best = models.Sequential()
         network_best.add(layers.Dense(512, activation='relu', input_shape=(28 * 28,)))
```

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

result_best = network_best.fit(train_images, train_labels, epochs=22, batch_size=512)
```

```
Epoch 1/22
50000/50000 [==============================] - 6s 120us/step - loss: 0.7277 - acc: 0.7573
Epoch 2/22
50000/50000 [==============================] - 6s 116us/step - loss: 0.2698 - acc: 0.9216
Epoch 3/22
50000/50000 [==============================] - 6s 119us/step - loss: 0.1967 - acc: 0.9440
Epoch 4/22
50000/50000 [==============================] - 6s 116us/step - loss: 0.1665 - acc: 0.9537
Epoch 5/22
50000/50000 [==============================] - 6s 122us/step - loss: 0.1394 - acc: 0.9604
Epoch 6/22
50000/50000 [==============================] - 6s 123us/step - loss: 0.1271 - acc: 0.9651
Epoch 7/22
50000/50000 [==============================] - 6s 126us/step - loss: 0.1162 - acc: 0.9674
Epoch 8/22
50000/50000 [==============================] - 6s 125us/step - loss: 0.1106 - acc: 0.9701
Epoch 9/22
50000/50000 [==============================] - 6s 124us/step - loss: 0.0986 - acc: 0.9724
Epoch 10/22
50000/50000 [==============================] - 6s 124us/step - loss: 0.0949 - acc: 0.9730
Epoch 11/22
50000/50000 [==============================] - 6s 121us/step - loss: 0.0880 - acc: 0.9763
Epoch 12/22
50000/50000 [==============================] - 6s 123us/step - loss: 0.0849 - acc: 0.9761
Epoch 13/22
50000/50000 [==============================] - 6s 122us/step - loss: 0.0827 - acc: 0.9769
Epoch 14/22
50000/50000 [==============================] - 6s 123us/step - loss: 0.0777 - acc: 0.9784
Epoch 15/22
50000/50000 [==============================] - 6s 123us/step - loss: 0.0730 - acc: 0.9800
Epoch 16/22
50000/50000 [==============================] - 6s 126us/step - loss: 0.0751 - acc: 0.9794
Epoch 17/22
50000/50000 [==============================] - 6s 123us/step - loss: 0.0740 - acc: 0.9797
Epoch 18/22
50000/50000 [==============================] - 6s 124us/step - loss: 0.0689 - acc: 0.9819
```

```
Epoch 19/22
50000/50000 [==============================] - 6s 124us/step - loss: 0.0685 - acc: 0.9819
Epoch 20/22
50000/50000 [==============================] - 6s 124us/step - loss: 0.0675 - acc: 0.9816
Epoch 21/22
50000/50000 [==============================] - 6s 127us/step - loss: 0.0655 - acc: 0.9834
Epoch 22/22
50000/50000 [==============================] - 6s 125us/step - loss: 0.0652 - acc: 0.9828
```

```
In [15]: network_best.evaluate(test_images, test_labels)
```

```
10000/10000 [==============================] - 2s 152us/step
```

```
Out[15]: [0.07913323289608848, 0.9838]
```

The test set loss and accuracy of the 0.07913 and 0.9838. Compared with the baseline model from chapter 2.1 in the book, whose test accuracy is 0.9785, my model is better.

2 Part 2: Scalar regression

1. Initial model

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

        (train_data, train_targets), (test_data, test_targets) = boston_housing.load_data()
        mean = train_data.mean(axis=0)
        train_data -= mean
        std = train_data.std(axis=0)
        train_data /= std
        test_data -= mean
        test_data /= std
```

```
c:\users\liaoa\appdata\local\programs\python\python36\lib\site-packages\h5py\__init__.py:36: Fu
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

```
Downloading data from https://s3.amazonaws.com/keras-datasets/boston_housing.npz
57344/57026 [==============================] - 0s 3us/step
```

```
In [2]: from keras import models
        from keras import layers

        def build_model():
            model = models.Sequential()
            model.add(layers.Dense(64, activation='relu', input_shape=(train_data.shape[1],)))
```

```
            model.add(layers.Dense(64, activation='relu'))
            model.add(layers.Dense(1))
            model.compile(optimizer='rmsprop', loss='mse', metrics=['mse'])
            return model
```

```
In [15]: import numpy as np
         k = 10
         num_val_samples = len(train_data) // k
         num_epochs = 500
```

```
In [7]: def train_model():
            all_mse_histories = []
            for i in range(k):
                print('processing fold #', i)
                val_data = train_data[i * num_val_samples: (i + 1) * num_val_samples]
                val_targets = train_targets[i * num_val_samples: (i + 1) * num_val_samples]
                partial_train_data = np.concatenate([train_data[:i * num_val_samples], train_da
                partial_train_targets = np.concatenate([train_targets[:i * num_val_samples], tr
                model = build_model()
                history = model.fit(partial_train_data, partial_train_targets, validation_data=
                mse_history = history.history['mean_squared_error']
                all_mse_histories.append(mse_history)
            return all_mse_histories
```

```
In [13]: import matplotlib.pyplot as plt
         %matplotlib inline

         def smooth_curve(points, factor=0.9):
             smoothed_points = []
             for point in points:
                 if smoothed_points:
                     previous = smoothed_points[-1]
                     smoothed_points.append(previous * factor + point * (1 - factor))
                 else:
                     smoothed_points.append(point)
             return smoothed_points

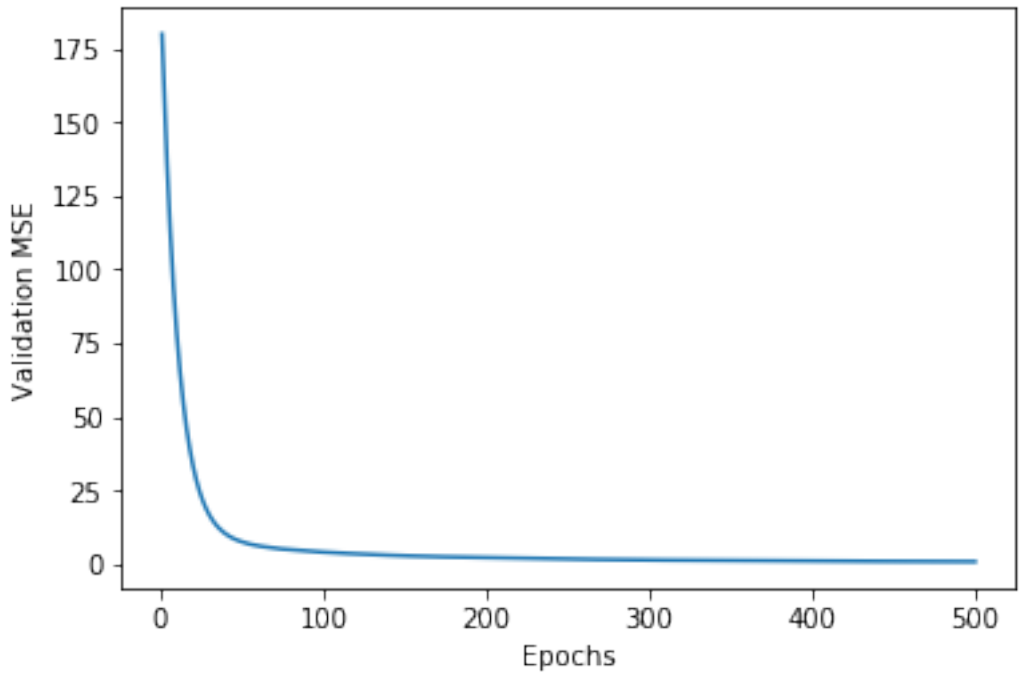
         def plot_curve(average_mse_history):
             smooth_mse_history = smooth_curve(average_mse_history)
             plt.plot(range(1, len(smooth_mse_history) + 1), smooth_mse_history)
             plt.xlabel('Epochs')
             plt.ylabel('Validation MSE')
             plt.show()
```

```
In [17]: all_mse_histories_org = train_model()
         average_mse_history_org = [np.mean([x[n] for x in all_mse_histories_org]) for n in ran
```

```
processing fold # 0
processing fold # 1
```

```
processing fold # 2
processing fold # 3
processing fold # 4
processing fold # 5
processing fold # 6
processing fold # 7
processing fold # 8
processing fold # 9
```

In [18]:
```
plot_curve(average_mse_history_org)
```



In [20]:
```
model_org = build_model()
```

In [24]:
```
model_org.fit(train_data, train_targets, epochs = 500, batch_size = 16, verbose=0)
test_mse_score, test_mse_score = model_org.evaluate(test_data, test_targets)

print("test_mse_score", test_mse_score)
```

```
102/102 [==============================] - 0s 0us/step
test_mse_score 13.267143473905676
```

In [34]:
```
model_org.fit(train_data, train_targets, epochs = 500, batch_size = 64, verbose=0)
test_mse_score, test_mse_score = model_org.evaluate(test_data, test_targets)

print("test_mse_score", test_mse_score)
```

```
102/102 [==============================] - 0s 0us/step
test_mse_score 13.935257780785655
```

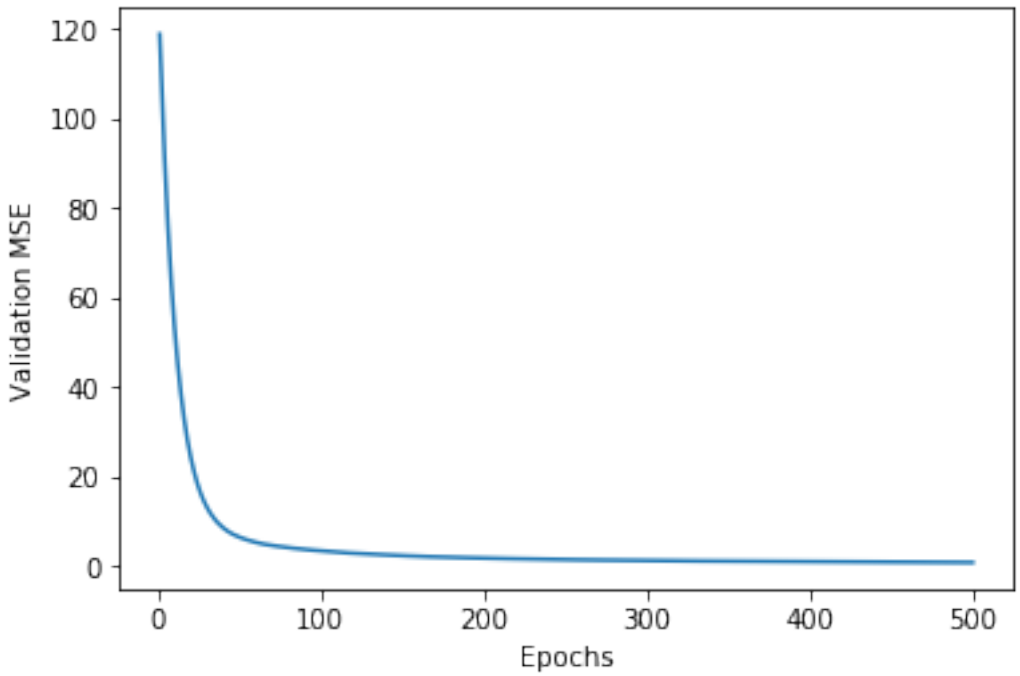
Try on different models - Adding a dense layer

```
In [25]: def build_model():
             model = models.Sequential()
             model.add(layers.Dense(64, activation='relu', input_shape=(train_data.shape[1],)))
             model.add(layers.Dense(64, activation='relu'))
             model.add(layers.Dense(64, activation='relu'))
             model.add(layers.Dense(1))
             model.compile(optimizer='rmsprop', loss='mse', metrics=['mse'])
             return model

In [26]: all_mse_histories_more = train_model()
         average_mse_history_more = [np.mean([x[i] for x in all_mse_histories_more]) for i in r

processing fold # 0
processing fold # 1
processing fold # 2
processing fold # 3
processing fold # 4
processing fold # 5
processing fold # 6
processing fold # 7
processing fold # 8
processing fold # 9


In [27]: plot_curve(average_mse_history_more)
```




```
In [28]: model_more = build_model()

In [33]: model_more.fit(train_data, train_targets, epochs=500, batch_size=16, verbose=0)
         test_mse_score, test_mse_score = model_more.evaluate(test_data, test_targets)

         print("test_mse_score", test_mse_score)

102/102 [==============================] - 0s 0us/step
test_mse_score 12.586411719228707


In [32]: model_more.fit(train_data, train_targets, epochs=500, batch_size=64, verbose=0)
         test_mse_score, test_mse_score = model_more.evaluate(test_data, test_targets)

         print("test_mse_score", test_mse_score)

102/102 [==============================] - 0s 68us/step
test_mse_score 13.877640069699755
```

Try on different models - Adding dropout layers

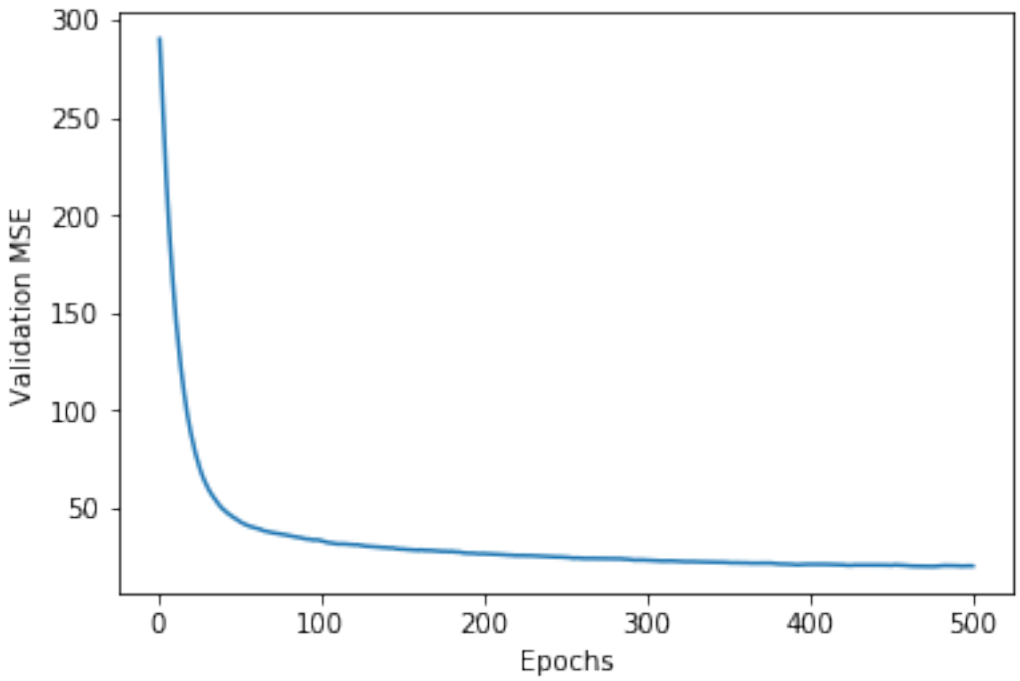
```
In [35]: def build_model():
             model = models.Sequential()
             model.add(layers.Dense(64, activation='relu', input_shape=(train_data.shape[1],)))
```

```
            model.add(layers.Dropout(0.5))
            model.add(layers.Dense(64, activation='relu'))
            model.add(layers.Dropout(0.5))
            model.add(layers.Dense(64, activation='relu'))
            model.add(layers.Dropout(0.5))
            model.add(layers.Dense(1))
            model.compile(optimizer='rmsprop', loss='mse', metrics=['mse'])
            return model
```

```
In [36]: all_mse_histories_dropout = train_model()
         average_mse_history_dropout = [np.mean([x[i] for x in all_mse_histories_dropout]) for
```

```
processing fold # 0
processing fold # 1
processing fold # 2
processing fold # 3
processing fold # 4
processing fold # 5
processing fold # 6
processing fold # 7
processing fold # 8
processing fold # 9
```

```
In [37]: plot_curve(average_mse_history_dropout)
```



```
In [38]: model_dropout = build_model()

In [42]: model_dropout.fit(train_data, train_targets, epochs=500, batch_size=16, verbose=0)
         test_mse_score, test_mse_score = model_dropout.evaluate(test_data, test_targets)

         print("test_mse_score", test_mse_score)

102/102 [==============================] - 0s 49us/step
test_mse_score 19.377425848268995


In [40]: model_dropout.fit(train_data, train_targets, epochs=500, batch_size=64, verbose=0)
         test_mse_score, test_mse_score = model_dropout.evaluate(test_data, test_targets)

         print("test_mse_score", test_mse_score)

102/102 [==============================] - 0s 67us/step
test_mse_score 17.436082578172872
```

Try on different models - Adding penalty

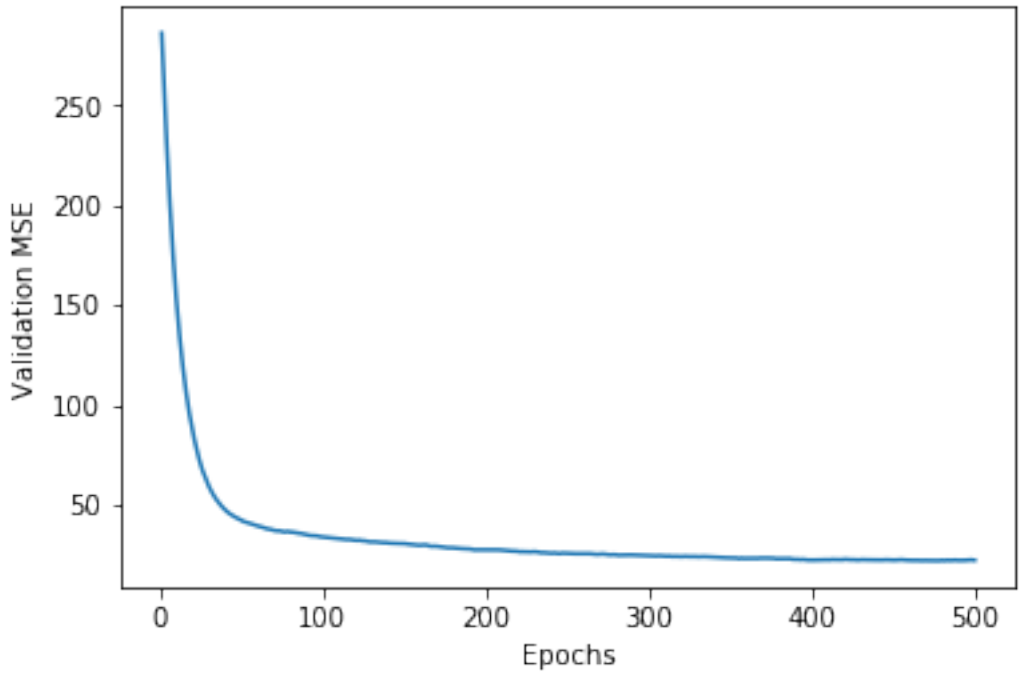
```
In [46]: from keras import regularizers

         def build_model():
             model = models.Sequential()
             model.add(layers.Dense(64, activation='relu', input_shape=(train_data.shape[1],),
             model.add(layers.Dropout(0.5))
             model.add(layers.Dense(64, activation='relu', kernel_regularizer=regularizers.l2(
             model.add(layers.Dropout(0.5))
             model.add(layers.Dense(64, activation='relu', kernel_regularizer=regularizers.l2(
             model.add(layers.Dropout(0.5))
             model.add(layers.Dense(1))
             model.compile(optimizer='rmsprop', loss='mse', metrics=['mse'])
             return model

In [47]: all_mse_histories_penalty = train_model()
         average_mse_history_penalty = [np.mean([x[i] for x in all_mse_histories_penalty]) for

processing fold # 0
processing fold # 1
processing fold # 2
processing fold # 3
processing fold # 4
processing fold # 5
processing fold # 6
processing fold # 7
processing fold # 8
processing fold # 9
```

```
In [48]: plot_curve(average_mse_history_penalty)
```




```
In [49]: model_penalty = build_model()

In [50]: model_penalty.fit(train_data, train_targets, epochs=500, batch_size=16, verbose=0)
         test_mse_score, test_mse_score = model_penalty.evaluate(test_data, test_targets)

         print("test_mse_score", test_mse_score)

102/102 [==============================] - 0s 4ms/step
test_mse_score 17.785012338675706
```

The best model is here!

```
In [51]: model_more.fit(train_data, train_targets, epochs=500, batch_size=16, verbose=0)
         test_mse_score, test_mse_score = model_more.evaluate(test_data, test_targets)

         print("The best test_mse_score", test_mse_score)

102/102 [==============================] - 0s 142us/step
The best test_mse_score 12.933781044155944
```