Classification Using Neural Networks and Deep Learning

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1. INTRODUCTION

The project's objective is to recognize handwritten numbers using a convolutional neural network. With just 6000 samples used for training and 1000 samples for testing, the dataset is a subset of the MNIST dataset.

2. Methods

Experimenting with a convolutional neural network using the following parameter settings:

1. The image's size (28 x 28) is the input size.
2. A convolutional layer with 6 feature maps makes up the first layer. The size of the convolution kernels is 3 x 3 and the stride is 1.
3. A max pooling layer is the following layer. The pooling is 2 x 2.
4. The third layer is another convolutional layer, which has 16 feature maps. The size of the convolution kernels is 3 x 3 and the stride is 1.
5. Followed by another max pooling layer. The pooling is the same 2 x 2.
6. After that, the layer is fully connected to the next layer with 120 nodes and ReLU as the activation function.
7. And another fully connected layer with 84 nodes and ReLU as the activation function.
8. The final layer uses softmax with output nodes corresponding to the class number.

Change the parameter settings and conduct experiment again:

1. Change the size of the convolution kernels to 5 x 5.
2. Change the number of the feature maps in the first and second convolutional layers.

3. RESULTS

1. Base line

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
Epoch 1/12
469/469 [==============================] - 28s 55ms/step - loss: 0.8104 - accuracy: 0.7640 - val_loss: 0.2790 - val_accuracy: 0.9218
Epoch 2/12
469/469 [==============================] - 16s 34ms/step - loss: 0.2405 - accuracy: 0.9286 - val_loss: 0.2064 - val_accuracy: 0.9398
Epoch 3/12
469/469 [==============================] - 16s 35ms/step - loss: 0.1852 - accuracy: 0.9449 - val_loss: 0.1614 - val_accuracy: 0.9534
Epoch 4/12
469/469 [==============================] - 18s 38ms/step - loss: 0.1554 - accuracy: 0.9537 - val_loss: 0.1340 - val_accuracy: 0.9615
Epoch 5/12
469/469 [==============================] - 16s 35ms/step - loss: 0.1346 - accuracy: 0.9599 - val_loss: 0.1171 - val_accuracy: 0.9655
Epoch 6/12
469/469 [==============================] - 18s 39ms/step - loss: 0.1188 - accuracy: 0.9642 - val_loss: 0.1133 - val_accuracy: 0.9657
Epoch 7/12
469/469 [==============================] - 17s 37ms/step - loss: 0.1078 - accuracy: 0.9677 - val_loss: 0.1020 - val_accuracy: 0.9686
Epoch 8/12
469/469 [==============================] - 16s 35ms/step - loss: 0.0986 - accuracy: 0.9699 - val_loss: 0.0985 - val_accuracy: 0.9708
Epoch 9/12
469/469 [==============================] - 16s 35ms/step - loss: 0.0913 - accuracy: 0.9728 - val_loss: 0.0874 - val_accuracy: 0.9729
Epoch 10/12
469/469 [==============================] - 18s 38ms/step - loss: 0.0850 - accuracy: 0.9741 - val_loss: 0.0805 - val_accuracy: 0.9747
Epoch 11/12
469/469 [==============================] - 16s 34ms/step - loss: 0.0796 - accuracy: 0.9760 - val_loss: 0.0785 - val_accuracy: 0.9752
Epoch 12/12
469/469 [==============================] - 16s 34ms/step - loss: 0.0752 - accuracy: 0.9768 - val_loss: 0.0744 - val_accuracy: 0.9768
Test loss: 0.07444515079259872
Test accuracy: 0.9768000245094299
```

2. kernels size 5 x 5: better results

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
Epoch 1/12
469/469 [==============================] - 20s 41ms/step - loss: 0.8097 - accuracy: 0.7588 - val_loss: 0.2679 - val_accuracy: 0.9189
Epoch 2/12
469/469 [==============================] - 20s 43ms/step - loss: 0.2252 - accuracy: 0.9322 - val_loss: 0.1843 - val_accuracy: 0.9441
Epoch 3/12
469/469 [==============================] - 27s 58ms/step - loss: 0.1687 - accuracy: 0.9493 - val_loss: 0.1415 - val_accuracy: 0.9575
Epoch 4/12
469/469 [==============================] - 19s 41ms/step - loss: 0.1382 - accuracy: 0.9579 - val_loss: 0.1205 - val_accuracy: 0.9624
Epoch 5/12
469/469 [==============================] - 21s 44ms/step - loss: 0.1191 - accuracy: 0.9635 - val_loss: 0.0994 - val_accuracy: 0.9703
Epoch 6/12
469/469 [==============================] - 21s 45ms/step - loss: 0.1047 - accuracy: 0.9683 - val_loss: 0.0858 - val_accuracy: 0.9731
Epoch 7/12
469/469 [==============================] - 20s 42ms/step - loss: 0.0950 - accuracy: 0.9708 - val_loss: 0.0914 - val_accuracy: 0.9698
Epoch 8/12
469/469 [==============================] - 21s 44ms/step - loss: 0.0869 - accuracy: 0.9735 - val_loss: 0.0886 - val_accuracy: 0.9724
Epoch 9/12
469/469 [==============================] - 20s 42ms/step - loss: 0.0813 - accuracy: 0.9751 - val_loss: 0.0696 - val_accuracy: 0.9786
Epoch 10/12
469/469 [==============================] - 20s 43ms/step - loss: 0.0759 - accuracy: 0.9769 - val_loss: 0.0660 - val_accuracy: 0.9794
Epoch 11/12
469/469 [==============================] - 21s 45ms/step - loss: 0.0715 - accuracy: 0.9777 - val_loss: 0.0646 - val_accuracy: 0.9791
Epoch 12/12
469/469 [==============================] - 19s 41ms/step - loss: 0.0675 - accuracy: 0.9797 - val_loss: 0.0618 - val_accuracy: 0.9805
Test loss: 0.061817992478609085
Test accuracy: 0.9804999828338623
```

3. feature maps 6, 16 to 2, 4: worse results

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
Epoch 1/12
469/469 [==============================] - 19s 40ms/step - loss: 0.9532 - accuracy: 0.7010 - val_loss: 0.3314 - val_accuracy: 0.8998
Epoch 2/12
469/469 [==============================] - 17s 36ms/step - loss: 0.3043 - accuracy: 0.9072 - val_loss: 0.2495 - val_accuracy: 0.9246
Epoch 3/12
469/469 [==============================] - 17s 36ms/step - loss: 0.2481 - accuracy: 0.9241 - val_loss: 0.2140 - val_accuracy: 0.9352
Epoch 4/12
469/469 [==============================] - 18s 38ms/step - loss: 0.2172 - accuracy: 0.9348 - val_loss: 0.1898 - val_accuracy: 0.9442
Epoch 5/12
469/469 [==============================] - 17s 35ms/step - loss: 0.1954 - accuracy: 0.9409 - val_loss: 0.1701 - val_accuracy: 0.9497
Epoch 6/12
469/469 [==============================] - 17s 36ms/step - loss: 0.1788 - accuracy: 0.9455 - val_loss: 0.1558 - val_accuracy: 0.9534
Epoch 7/12
469/469 [==============================] - 19s 41ms/step - loss: 0.1653 - accuracy: 0.9495 - val_loss: 0.1502 - val_accuracy: 0.9528
Epoch 8/12
469/469 [==============================] - 17s 36ms/step - loss: 0.1552 - accuracy: 0.9531 - val_loss: 0.1362 - val_accuracy: 0.9576
Epoch 9/12
469/469 [==============================] - 17s 36ms/step - loss: 0.1463 - accuracy: 0.9551 - val_loss: 0.1306 - val_accuracy: 0.9589
Epoch 10/12
469/469 [==============================] - 18s 38ms/step - loss: 0.1385 - accuracy: 0.9570 - val_loss: 0.1241 - val_accuracy: 0.9610
Epoch 11/12
469/469 [==============================] - 17s 35ms/step - loss: 0.1324 - accuracy: 0.9590 - val_loss: 0.1175 - val_accuracy: 0.9615
Epoch 12/12
469/469 [==============================] - 17s 35ms/step - loss: 0.1272 - accuracy: 0.9611 - val_loss: 0.1142 - val_accuracy: 0.9638
Test loss: 0.11415040493011475
Test accuracy: 0.9638000130653381
```