Neural Networks image recognition - MultiLayer Perceptron

Use both MLNN for the following problem.

1. Add random noise (see below on `size parameter` on `np.random.normal`) to the images in training and testing. **Make sure each image gets a different noise feature added to it. Inspect by printing out several images. Note - the `size` parameter should match the data.**
2. Compare the `accuracy` of train and val after N epochs for MLNN with and without noise.
3. Vary the amount of noise by changing the `scale` parameter in `np.random.normal` by a factor. Use `.1, .5, 1.0, 2.0, 4.0` for the `scale` and keep track of the `accuracy` for training and validation and plot these results.

`np.random.normal`

Parameters

loc

Mean (“centre”) of the distribution.

scale

Standard deviation (spread or “width”) of the distribution. Must be non-negative.

size

Output shape. If the given shape is, e.g., (m, n, k), then m *n* k samples are drawn. If size is None (default), a single value is returned if loc and scale are both scalars. Otherwise, np.broadcast(loc, scale).size samples are drawn.

Neural Networks - Image Recognition

In [102…
```
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.optimizers import RMSprop
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend

import numpy as np
```

In [103…
```
import matplotlib.pyplot as  plt
%matplotlib inline
from IPython.display import display
```

Multi Layer Neural Network

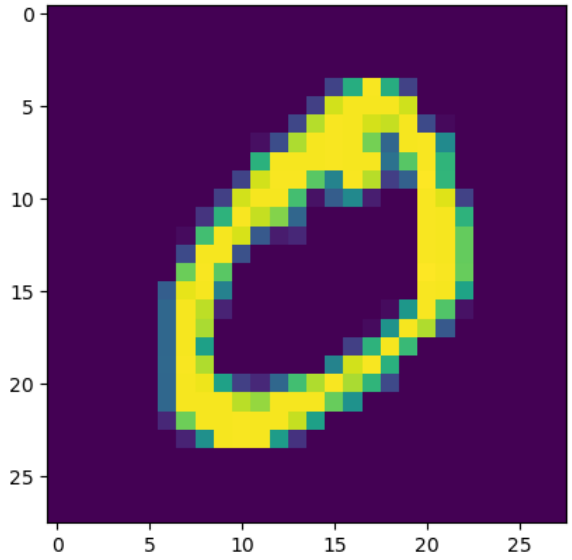
Trains a simple deep NN on the MNIST dataset. Gets to 98.40% test accuracy after 20 epochs (there is *a lot* of margin for parameter tuning).

In [104…
```
# the data, shuffled and split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [105…
```
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)

model = Sequential()
```

In [106…
```
print("original, no noise")
plt.imshow(x_train[1])
```

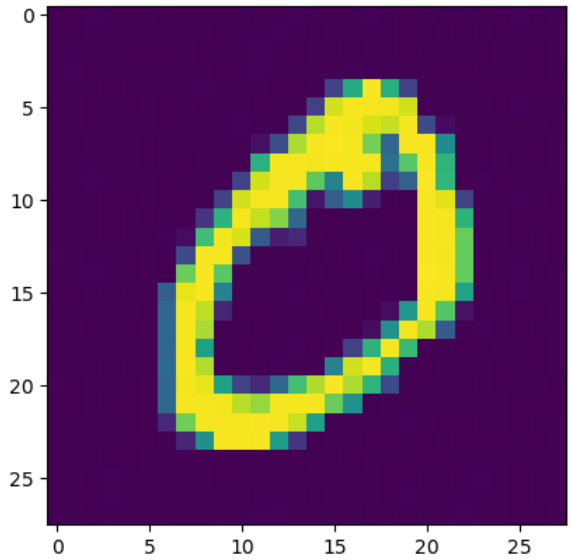
Out[106]:
```
original, no noise
<matplotlib.image.AxesImage at 0x2467a19d850>
```



In [107…
```
noisy = x_train + np.random.normal(0,.5,(60000,28,28))
print("a little noise added")
plt.imshow(noisy[1])
```

```
a little noise added
<matplotlib.image.AxesImage at 0x24670867b80>
```

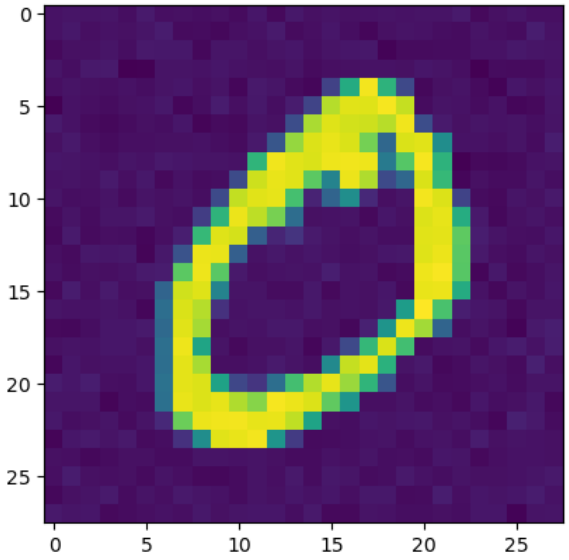
Out[107]:



In [108…
```
noisy2 = x_train + np.random.normal(0,4,(60000,28,28))
print("very noisy")
plt.imshow(noisy2[1])
```

```
very noisy
<matplotlib.image.AxesImage at 0x24670a1e4f0>
```

Out[108]:



In [109…

```
scale = [0, 0.1, 0.5, 1.0, 2.0, 4.0]
batch_size = 128
num_classes = 10
epochs = 20
# Noise is added here
# The max value of the noise should not grossly surpass 1.0
for s in scale:
    noise_train = np.random.normal(0, s, size=(60000, 28, 28))
    new_train = noise_train + x_train
    noise_test = np.random.normal(0, s, size=(10000, 28, 28))
    new_test = noise_test + x_test

    new_train = new_train.reshape(60000, 784)
    new_test = new_test.reshape(10000, 784)
    new_train = new_train.astype('float32')
    new_test = new_test.astype('float32')
    new_train /= 255
    new_test /= 255

    model.add(Dense(512, activation='relu', input_shape=(784,)))
    model.add(Dropout(0.2))
    model.add(Dense(512, activation='relu'))
    model.add(Dropout(0.2))
    model.add(Dense(10, activation='softmax'))

    model.summary()
    model.compile(loss='categorical_crossentropy',
                  optimizer="adam",
                  metrics=['accuracy'])

    model.fit(new_train, y_train,
              batch_size=batch_size,
              epochs=epochs,
              verbose=1,
              validation_data=(new_test, y_test))

    score = model.evaluate(new_test, y_test, verbose=0)
    print('Scores for noise scale ' + str(s))
    print('Test loss:', score[0])
    print('Test accuracy:', score[1])
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_39 (Dense)            (None, 512)               401920

 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

=================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 10s 14ms/step - loss: 0.2508 - accuracy: 0.9258 - val_loss: 0.1025 - val_accuracy: 0.96
85
Epoch 2/20
469/469 [==============================] - 6s 13ms/step - loss: 0.1020 - accuracy: 0.9685 - val_loss: 0.0875 - val_accuracy: 0.972
3
Epoch 3/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0713 - accuracy: 0.9773 - val_loss: 0.0676 - val_accuracy: 0.979
0
Epoch 4/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0558 - accuracy: 0.9826 - val_loss: 0.0742 - val_accuracy: 0.977
1
Epoch 5/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0443 - accuracy: 0.9854 - val_loss: 0.0834 - val_accuracy: 0.974
5
Epoch 6/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0397 - accuracy: 0.9870 - val_loss: 0.0684 - val_accuracy: 0.979
5
Epoch 7/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0334 - accuracy: 0.9886 - val_loss: 0.0713 - val_accuracy: 0.980
5
Epoch 8/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0300 - accuracy: 0.9899 - val_loss: 0.0730 - val_accuracy: 0.979
5
Epoch 9/20
469/469 [==============================] - 5s 11ms/step - loss: 0.0280 - accuracy: 0.9901 - val_loss: 0.0657 - val_accuracy: 0.982
2
Epoch 10/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0258 - accuracy: 0.9913 - val_loss: 0.0761 - val_accuracy: 0.979
6
Epoch 11/20
469/469 [==============================] - 5s 11ms/step - loss: 0.0216 - accuracy: 0.9924 - val_loss: 0.0771 - val_accuracy: 0.981
2
Epoch 12/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0218 - accuracy: 0.9930 - val_loss: 0.0719 - val_accuracy: 0.981
5
Epoch 13/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0212 - accuracy: 0.9928 - val_loss: 0.0764 - val_accuracy: 0.982
1
Epoch 14/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0190 - accuracy: 0.9936 - val_loss: 0.0951 - val_accuracy: 0.976
9
Epoch 15/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0178 - accuracy: 0.9941 - val_loss: 0.0738 - val_accuracy: 0.982
5
Epoch 16/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0152 - accuracy: 0.9948 - val_loss: 0.0811 - val_accuracy: 0.982
6
Epoch 17/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0203 - accuracy: 0.9932 - val_loss: 0.0764 - val_accuracy: 0.982
8
Epoch 18/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0141 - accuracy: 0.9956 - val_loss: 0.0860 - val_accuracy: 0.979
9
Epoch 19/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0183 - accuracy: 0.9939 - val_loss: 0.0801 - val_accuracy: 0.983
2
Epoch 20/20
469/469 [==============================] - 5s 10ms/step - loss: 0.0143 - accuracy: 0.9954 - val_loss: 0.0777 - val_accuracy: 0.983
9
Scores for noise scale 0
Test loss: 0.07769788056612015
Test accuracy: 0.9839000105857849
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
```

```
 dense_39 (Dense)            (None, 512)               401920

 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

 dense_42 (Dense)            (None, 512)               5632

 dropout_28 (Dropout)        (None, 512)               0

 dense_43 (Dense)            (None, 512)               262656

 dropout_29 (Dropout)        (None, 512)               0

 dense_44 (Dense)            (None, 10)                5130

=================================================================
Total params: 943,124
Trainable params: 943,124
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 12s 19ms/step - loss: 0.1066 - accuracy: 0.9893 - val_loss: 0.1364 - val_accuracy: 0.97
89
Epoch 2/20
469/469 [==============================] - 8s 18ms/step - loss: 0.0554 - accuracy: 0.9906 - val_loss: 0.1265 - val_accuracy: 0.980
3
Epoch 3/20
469/469 [==============================] - 6s 14ms/step - loss: 0.0535 - accuracy: 0.9908 - val_loss: 0.1233 - val_accuracy: 0.979
5
Epoch 4/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0433 - accuracy: 0.9924 - val_loss: 0.1075 - val_accuracy: 0.982
0
Epoch 5/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0367 - accuracy: 0.9932 - val_loss: 0.0984 - val_accuracy: 0.982
7
Epoch 6/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0348 - accuracy: 0.9934 - val_loss: 0.1260 - val_accuracy: 0.979
1
Epoch 7/20
469/469 [==============================] - 6s 13ms/step - loss: 0.0322 - accuracy: 0.9936 - val_loss: 0.1269 - val_accuracy: 0.980
4
Epoch 8/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0300 - accuracy: 0.9938 - val_loss: 0.0980 - val_accuracy: 0.984
0
Epoch 9/20
469/469 [==============================] - 7s 15ms/step - loss: 0.0232 - accuracy: 0.9949 - val_loss: 0.0975 - val_accuracy: 0.983
6
Epoch 10/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0271 - accuracy: 0.9940 - val_loss: 0.0980 - val_accuracy: 0.983
2
Epoch 11/20
469/469 [==============================] - 7s 15ms/step - loss: 0.0292 - accuracy: 0.9935 - val_loss: 0.0998 - val_accuracy: 0.982
5
Epoch 12/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0299 - accuracy: 0.9934 - val_loss: 0.1039 - val_accuracy: 0.980
1
Epoch 13/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0232 - accuracy: 0.9948 - val_loss: 0.0865 - val_accuracy: 0.982
5
Epoch 14/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0251 - accuracy: 0.9941 - val_loss: 0.1090 - val_accuracy: 0.979
6
Epoch 15/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0236 - accuracy: 0.9948 - val_loss: 0.0997 - val_accuracy: 0.983
4
Epoch 16/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0268 - accuracy: 0.9942 - val_loss: 0.0856 - val_accuracy: 0.983
2
Epoch 17/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0295 - accuracy: 0.9938 - val_loss: 0.0986 - val_accuracy: 0.981
4
Epoch 18/20
469/469 [==============================] - 6s 14ms/step - loss: 0.0226 - accuracy: 0.9947 - val_loss: 0.1006 - val_accuracy: 0.983
5
Epoch 19/20
469/469 [==============================] - 7s 15ms/step - loss: 0.0258 - accuracy: 0.9938 - val_loss: 0.0886 - val_accuracy: 0.983
5
Epoch 20/20
469/469 [==============================] - 7s 14ms/step - loss: 0.0265 - accuracy: 0.9940 - val_loss: 0.1049 - val_accuracy: 0.980
0
Scores for noise scale 0.1
```

```
Test loss: 0.10485726594924927
Test accuracy: 0.9800000190734863
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_39 (Dense)            (None, 512)               401920

 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

 dense_42 (Dense)            (None, 512)               5632

 dropout_28 (Dropout)        (None, 512)               0

 dense_43 (Dense)            (None, 512)               262656

 dropout_29 (Dropout)        (None, 512)               0

 dense_44 (Dense)            (None, 10)                5130

 dense_45 (Dense)            (None, 512)               5632

 dropout_30 (Dropout)        (None, 512)               0

 dense_46 (Dense)            (None, 512)               262656

 dropout_31 (Dropout)        (None, 512)               0

 dense_47 (Dense)            (None, 10)                5130

=================================================================
Total params: 1,216,542
Trainable params: 1,216,542
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 17s 28ms/step - loss: 0.0987 - accuracy: 0.9905 - val_loss: 0.1081 - val_accuracy: 0.98
28
Epoch 2/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0375 - accuracy: 0.9931 - val_loss: 0.1096 - val_accuracy: 0.98
28
Epoch 3/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0337 - accuracy: 0.9934 - val_loss: 0.1138 - val_accuracy: 0.98
10
Epoch 4/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0370 - accuracy: 0.9926 - val_loss: 0.1123 - val_accuracy: 0.98
10
Epoch 5/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0380 - accuracy: 0.9932 - val_loss: 0.1454 - val_accuracy: 0.97
90
Epoch 6/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0396 - accuracy: 0.9928 - val_loss: 0.1222 - val_accuracy: 0.98
08
Epoch 7/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0434 - accuracy: 0.9923 - val_loss: 0.1203 - val_accuracy: 0.98
10
Epoch 8/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0484 - accuracy: 0.9912 - val_loss: 0.1192 - val_accuracy: 0.98
07
Epoch 9/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0406 - accuracy: 0.9928 - val_loss: 0.1234 - val_accuracy: 0.98
14
Epoch 10/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0434 - accuracy: 0.9926 - val_loss: 0.1183 - val_accuracy: 0.98
07
Epoch 11/20
469/469 [==============================] - 11s 23ms/step - loss: 0.0494 - accuracy: 0.9918 - val_loss: 0.1174 - val_accuracy: 0.98
12
Epoch 12/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0492 - accuracy: 0.9915 - val_loss: 0.1362 - val_accuracy: 0.97
81
Epoch 13/20
469/469 [==============================] - 10s 22ms/step - loss: 0.0458 - accuracy: 0.9916 - val_loss: 0.1240 - val_accuracy: 0.98
11
Epoch 14/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0531 - accuracy: 0.9901 - val_loss: 0.1192 - val_accuracy: 0.97
91
Epoch 15/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0525 - accuracy: 0.9898 - val_loss: 0.1186 - val_accuracy: 0.98
17
```

```
Epoch 16/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0459 - accuracy: 0.9922 - val_loss: 0.1193 - val_accuracy: 0.98
07
Epoch 17/20
469/469 [==============================] - 10s 20ms/step - loss: 0.0457 - accuracy: 0.9924 - val_loss: 0.1032 - val_accuracy: 0.98
32
Epoch 18/20
469/469 [==============================] - 9s 20ms/step - loss: 0.0502 - accuracy: 0.9913 - val_loss: 0.1132 - val_accuracy: 0.982
3
Epoch 19/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0452 - accuracy: 0.9921 - val_loss: 0.1193 - val_accuracy: 0.98
16
Epoch 20/20
469/469 [==============================] - 10s 21ms/step - loss: 0.0495 - accuracy: 0.9915 - val_loss: 0.1204 - val_accuracy: 0.98
07
Scores for noise scale 0.5
Test loss: 0.12037938088178635
Test accuracy: 0.9807000160217285
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_39 (Dense)            (None, 512)               401920

 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

 dense_42 (Dense)            (None, 512)               5632

 dropout_28 (Dropout)        (None, 512)               0

 dense_43 (Dense)            (None, 512)               262656

 dropout_29 (Dropout)        (None, 512)               0

 dense_44 (Dense)            (None, 10)                5130

 dense_45 (Dense)            (None, 512)               5632

 dropout_30 (Dropout)        (None, 512)               0

 dense_46 (Dense)            (None, 512)               262656

 dropout_31 (Dropout)        (None, 512)               0

 dense_47 (Dense)            (None, 10)                5130

 dense_48 (Dense)            (None, 512)               5632

 dropout_32 (Dropout)        (None, 512)               0

 dense_49 (Dense)            (None, 512)               262656

 dropout_33 (Dropout)        (None, 512)               0

 dense_50 (Dense)            (None, 10)                5130

=================================================================
Total params: 1,489,960
Trainable params: 1,489,960
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 16s 26ms/step - loss: 0.1098 - accuracy: 0.9892 - val_loss: 0.1212 - val_accuracy: 0.98
12
Epoch 2/20
469/469 [==============================] - 12s 25ms/step - loss: 0.0532 - accuracy: 0.9913 - val_loss: 0.1149 - val_accuracy: 0.98
22
Epoch 3/20
469/469 [==============================] - 12s 26ms/step - loss: 0.0543 - accuracy: 0.9911 - val_loss: 0.1098 - val_accuracy: 0.98
31
Epoch 4/20
469/469 [==============================] - 12s 26ms/step - loss: 0.0488 - accuracy: 0.9923 - val_loss: 0.1413 - val_accuracy: 0.97
96
Epoch 5/20
469/469 [==============================] - 12s 25ms/step - loss: 0.0693 - accuracy: 0.9889 - val_loss: 0.1355 - val_accuracy: 0.97
77
Epoch 6/20
469/469 [==============================] - 12s 25ms/step - loss: 0.0715 - accuracy: 0.9890 - val_loss: 0.1320 - val_accuracy: 0.98
05
Epoch 7/20
```

```
469/469 [==============================] - 11s 24ms/step - loss: 0.0702 - accuracy: 0.9891 - val_loss: 0.1543 - val_accuracy: 0.97
67
Epoch 8/20
469/469 [==============================] - 11s 24ms/step - loss: 0.1070 - accuracy: 0.9821 - val_loss: 0.1369 - val_accuracy: 0.97
99
Epoch 9/20
469/469 [==============================] - 11s 24ms/step - loss: 0.0909 - accuracy: 0.9852 - val_loss: 0.1346 - val_accuracy: 0.97
76
Epoch 10/20
469/469 [==============================] - 12s 26ms/step - loss: 0.0952 - accuracy: 0.9844 - val_loss: 0.1311 - val_accuracy: 0.97
92
Epoch 11/20
469/469 [==============================] - 12s 26ms/step - loss: 0.0980 - accuracy: 0.9847 - val_loss: 0.1539 - val_accuracy: 0.97
52
Epoch 12/20
469/469 [==============================] - 12s 26ms/step - loss: 0.1071 - accuracy: 0.9825 - val_loss: 0.1494 - val_accuracy: 0.97
62
Epoch 13/20
469/469 [==============================] - 12s 25ms/step - loss: 0.1199 - accuracy: 0.9803 - val_loss: 0.1439 - val_accuracy: 0.97
74
Epoch 14/20
469/469 [==============================] - 12s 26ms/step - loss: 0.1339 - accuracy: 0.9776 - val_loss: 0.1786 - val_accuracy: 0.97
13
Epoch 15/20
469/469 [==============================] - 12s 27ms/step - loss: 0.1361 - accuracy: 0.9765 - val_loss: 0.1597 - val_accuracy: 0.97
44
Epoch 16/20
469/469 [==============================] - 713s 2s/step - loss: 0.1450 - accuracy: 0.9737 - val_loss: 0.1693 - val_accuracy: 0.973
0
Epoch 17/20
469/469 [==============================] - 11s 24ms/step - loss: 0.1506 - accuracy: 0.9744 - val_loss: 0.1835 - val_accuracy: 0.97
08
Epoch 18/20
469/469 [==============================] - 13s 28ms/step - loss: 0.1241 - accuracy: 0.9797 - val_loss: 0.1605 - val_accuracy: 0.97
41
Epoch 19/20
469/469 [==============================] - 13s 27ms/step - loss: 0.1204 - accuracy: 0.9804 - val_loss: 0.1598 - val_accuracy: 0.97
38
Epoch 20/20
469/469 [==============================] - 13s 28ms/step - loss: 0.1289 - accuracy: 0.9784 - val_loss: 0.1763 - val_accuracy: 0.97
09
Scores for noise scale 1.0
Test loss: 0.1762864738702774
Test accuracy: 0.9708999991416931
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_39 (Dense)            (None, 512)               401920

 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

 dense_42 (Dense)            (None, 512)               5632

 dropout_28 (Dropout)        (None, 512)               0

 dense_43 (Dense)            (None, 512)               262656

 dropout_29 (Dropout)        (None, 512)               0

 dense_44 (Dense)            (None, 10)                5130

 dense_45 (Dense)            (None, 512)               5632

 dropout_30 (Dropout)        (None, 512)               0

 dense_46 (Dense)            (None, 512)               262656

 dropout_31 (Dropout)        (None, 512)               0

 dense_47 (Dense)            (None, 10)                5130

 dense_48 (Dense)            (None, 512)               5632

 dropout_32 (Dropout)        (None, 512)               0

 dense_49 (Dense)            (None, 512)               262656

 dropout_33 (Dropout)        (None, 512)               0
```

```
 dense_50 (Dense)            (None, 10)                5130

 dense_51 (Dense)            (None, 512)               5632

 dropout_34 (Dropout)        (None, 512)               0

 dense_52 (Dense)            (None, 512)               262656

 dropout_35 (Dropout)        (None, 512)               0

 dense_53 (Dense)            (None, 10)                5130

=================================================================
Total params: 1,763,378
Trainable params: 1,763,378
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 23s 38ms/step - loss: 0.1960 - accuracy: 0.9743 - val_loss: 0.1736 - val_accuracy: 0.97
28
Epoch 2/20
469/469 [==============================] - 15s 31ms/step - loss: 0.1804 - accuracy: 0.9684 - val_loss: 0.2119 - val_accuracy: 0.96
26
Epoch 3/20
469/469 [==============================] - 14s 30ms/step - loss: 0.1995 - accuracy: 0.9646 - val_loss: 0.2096 - val_accuracy: 0.96
01
Epoch 4/20
469/469 [==============================] - 15s 32ms/step - loss: 0.1991 - accuracy: 0.9649 - val_loss: 0.1966 - val_accuracy: 0.96
53
Epoch 5/20
469/469 [==============================] - 15s 33ms/step - loss: 0.1858 - accuracy: 0.9667 - val_loss: 0.1930 - val_accuracy: 0.96
80
Epoch 6/20
469/469 [==============================] - 15s 32ms/step - loss: 0.1784 - accuracy: 0.9692 - val_loss: 0.2196 - val_accuracy: 0.96
13
Epoch 7/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2086 - accuracy: 0.9629 - val_loss: 0.1934 - val_accuracy: 0.96
72
Epoch 8/20
469/469 [==============================] - 14s 30ms/step - loss: 0.1738 - accuracy: 0.9697 - val_loss: 0.1838 - val_accuracy: 0.97
15
Epoch 9/20
469/469 [==============================] - 14s 31ms/step - loss: 0.1601 - accuracy: 0.9730 - val_loss: 0.1747 - val_accuracy: 0.97
15
Epoch 10/20
469/469 [==============================] - 14s 30ms/step - loss: 0.1677 - accuracy: 0.9717 - val_loss: 0.2170 - val_accuracy: 0.96
42
Epoch 11/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2282 - accuracy: 0.9553 - val_loss: 0.2368 - val_accuracy: 0.95
52
Epoch 12/20
469/469 [==============================] - 14s 29ms/step - loss: 0.2080 - accuracy: 0.9611 - val_loss: 0.2294 - val_accuracy: 0.95
61
Epoch 13/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2651 - accuracy: 0.9469 - val_loss: 0.2522 - val_accuracy: 0.95
31
Epoch 14/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2241 - accuracy: 0.9592 - val_loss: 0.2108 - val_accuracy: 0.96
49
Epoch 15/20
469/469 [==============================] - 14s 31ms/step - loss: 0.2242 - accuracy: 0.9597 - val_loss: 0.2303 - val_accuracy: 0.95
81
Epoch 16/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2224 - accuracy: 0.9597 - val_loss: 0.1854 - val_accuracy: 0.96
95
Epoch 17/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2467 - accuracy: 0.9473 - val_loss: 0.3080 - val_accuracy: 0.92
06
Epoch 18/20
469/469 [==============================] - 14s 30ms/step - loss: 0.2531 - accuracy: 0.9502 - val_loss: 0.2386 - val_accuracy: 0.96
01
Epoch 19/20
469/469 [==============================] - 14s 31ms/step - loss: 0.2523 - accuracy: 0.9517 - val_loss: 0.2798 - val_accuracy: 0.94
90
Epoch 20/20
469/469 [==============================] - 14s 29ms/step - loss: 0.2491 - accuracy: 0.9541 - val_loss: 0.2333 - val_accuracy: 0.95
91
Scores for noise scale 2.0
Test loss: 0.233308807015419
Test accuracy: 0.9591000080108643
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_39 (Dense)            (None, 512)               401920
```

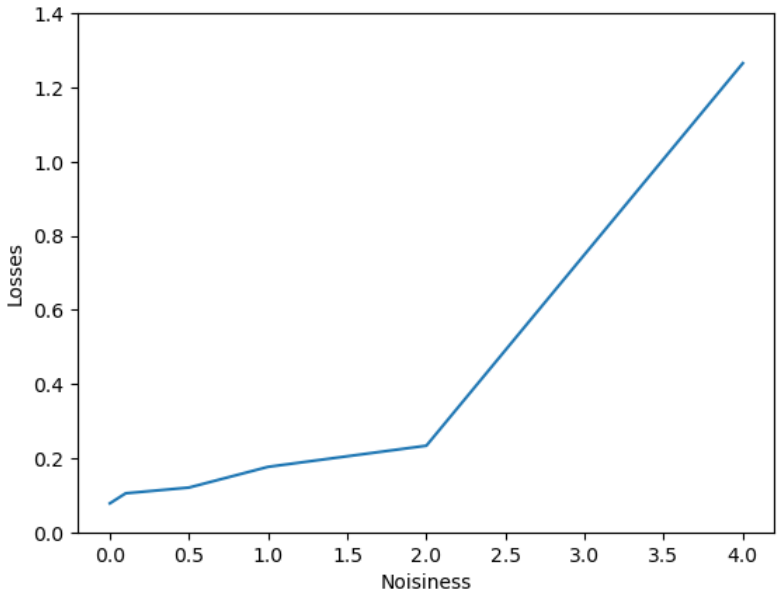
```
 dropout_26 (Dropout)        (None, 512)               0

 dense_40 (Dense)            (None, 512)               262656

 dropout_27 (Dropout)        (None, 512)               0

 dense_41 (Dense)            (None, 10)                5130

 dense_42 (Dense)            (None, 512)               5632

 dropout_28 (Dropout)        (None, 512)               0

 dense_43 (Dense)            (None, 512)               262656

 dropout_29 (Dropout)        (None, 512)               0

 dense_44 (Dense)            (None, 10)                5130

 dense_45 (Dense)            (None, 512)               5632

 dropout_30 (Dropout)        (None, 512)               0

 dense_46 (Dense)            (None, 512)               262656

 dropout_31 (Dropout)        (None, 512)               0

 dense_47 (Dense)            (None, 10)                5130

 dense_48 (Dense)            (None, 512)               5632

 dropout_32 (Dropout)        (None, 512)               0

 dense_49 (Dense)            (None, 512)               262656

 dropout_33 (Dropout)        (None, 512)               0

 dense_50 (Dense)            (None, 10)                5130

 dense_51 (Dense)            (None, 512)               5632

 dropout_34 (Dropout)        (None, 512)               0

 dense_52 (Dense)            (None, 512)               262656

 dropout_35 (Dropout)        (None, 512)               0

 dense_53 (Dense)            (None, 10)                5130

 dense_54 (Dense)            (None, 512)               5632

 dropout_36 (Dropout)        (None, 512)               0

 dense_55 (Dense)            (None, 512)               262656

 dropout_37 (Dropout)        (None, 512)               0

 dense_56 (Dense)            (None, 10)                5130

=================================================================
Total params: 2,036,796
Trainable params: 2,036,796
Non-trainable params: 0
_________________________________________________________________
Epoch 1/20
469/469 [==============================] - 22s 38ms/step - loss: 0.3320 - accuracy: 0.9433 - val_loss: 0.3415 - val_accuracy: 0.92
62
Epoch 2/20
469/469 [==============================] - 17s 37ms/step - loss: 0.4378 - accuracy: 0.8789 - val_loss: 0.4468 - val_accuracy: 0.87
10
Epoch 3/20
469/469 [==============================] - 15s 31ms/step - loss: 0.3376 - accuracy: 0.9237 - val_loss: 0.3357 - val_accuracy: 0.91
88
Epoch 4/20
469/469 [==============================] - 16s 34ms/step - loss: 0.3545 - accuracy: 0.9096 - val_loss: 0.3504 - val_accuracy: 0.91
23
Epoch 5/20
469/469 [==============================] - 16s 34ms/step - loss: 0.5081 - accuracy: 0.8572 - val_loss: 0.5264 - val_accuracy: 0.84
55
Epoch 6/20
469/469 [==============================] - 16s 34ms/step - loss: 0.5417 - accuracy: 0.8374 - val_loss: 0.6627 - val_accuracy: 0.77
39
Epoch 7/20
469/469 [==============================] - 16s 35ms/step - loss: 0.6509 - accuracy: 0.8030 - val_loss: 0.6186 - val_accuracy: 0.80
92
Epoch 8/20
469/469 [==============================] - 15s 33ms/step - loss: 0.6836 - accuracy: 0.7771 - val_loss: 0.5779 - val_accuracy: 0.80
```

```
34
Epoch 9/20
469/469 [==============================] - 16s 34ms/step - loss: 0.7000 - accuracy: 0.7410 - val_loss: 0.7051 - val_accuracy: 0.71
66
Epoch 10/20
469/469 [==============================] - 15s 31ms/step - loss: 0.7518 - accuracy: 0.6990 - val_loss: 0.8444 - val_accuracy: 0.67
02
Epoch 11/20
469/469 [==============================] - 16s 33ms/step - loss: 1.0483 - accuracy: 0.5979 - val_loss: 1.0719 - val_accuracy: 0.58
88
Epoch 12/20
469/469 [==============================] - 16s 33ms/step - loss: 1.0148 - accuracy: 0.6141 - val_loss: 0.8322 - val_accuracy: 0.67
91
Epoch 13/20
469/469 [==============================] - 16s 34ms/step - loss: 1.2156 - accuracy: 0.5461 - val_loss: 1.3663 - val_accuracy: 0.46
49
Epoch 14/20
469/469 [==============================] - 16s 34ms/step - loss: 1.2675 - accuracy: 0.4964 - val_loss: 1.2321 - val_accuracy: 0.48
64
Epoch 15/20
469/469 [==============================] - 17s 35ms/step - loss: 1.1191 - accuracy: 0.5296 - val_loss: 1.0299 - val_accuracy: 0.57
07
Epoch 16/20
469/469 [==============================] - 16s 34ms/step - loss: 1.0752 - accuracy: 0.5448 - val_loss: 1.0453 - val_accuracy: 0.57
15
Epoch 17/20
469/469 [==============================] - 15s 32ms/step - loss: 0.9758 - accuracy: 0.6197 - val_loss: 0.9282 - val_accuracy: 0.64
66
Epoch 18/20
469/469 [==============================] - 15s 32ms/step - loss: 1.1279 - accuracy: 0.5638 - val_loss: 1.2162 - val_accuracy: 0.52
56
Epoch 19/20
469/469 [==============================] - 15s 33ms/step - loss: 1.2785 - accuracy: 0.4974 - val_loss: 1.1748 - val_accuracy: 0.53
35
Epoch 20/20
469/469 [==============================] - 16s 34ms/step - loss: 1.2989 - accuracy: 0.5041 - val_loss: 1.2653 - val_accuracy: 0.50
87
Scores for noise scale 4.0
Test loss: 1.2652525901794434
Test accuracy: 0.5087000131607056
```

As expected increased noise increases losses and decreases accuracy

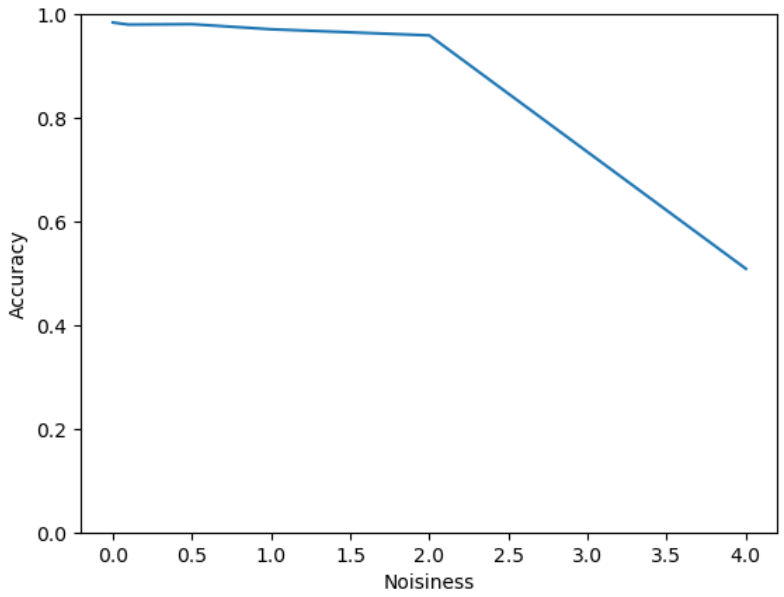
In [110…
```
losses = [0.0777, 0.1049, 0.1204, 0.1763, 0.2333, 1.2653]
accuracy = [0.9839, 0.9800, 0.9807, 0.9709, 0.9591, 0.5087]
```

In [113…
```
plt.figure()
plot = plt.plot(scale, losses)
plt.ylim([0, 1.4])
plt.xlabel('Noisiness')
plt.ylabel('Losses')
plt.show()
```



In [115…
```
plt.figure()
plot = plt.plot(scale, accuracy)
plt.ylim([0, 1])
```

```
plt.xlabel('Noisiness')
plt.ylabel('Accuracy')
plt.show()
```



In [ ]: