Casey Masamitsu | Week 11 | MLNN

Neural Networks image recognition - ConvNet

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.
4. Compare these results with the previous week where we used a MultiLayer Perceptron (this week we use a ConvNet).

Neural Networks - Image Recognition

In [11]:
```
import tensorflow as tf
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from tensorflow.keras.optimizers import RMSprop
from keras import backend
```

In [12]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as  plt
%matplotlib inline
```

Conv Net

Trains a simple convnet on the MNIST dataset. Gets to 99.25% test accuracy after 12 epochs (there is still a lot of margin for parameter tuning).

In [34]:
```
# input image dimensions
img_rows, img_cols = 28, 28

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

if backend.image_data_format() == 'channels_first':
```

```
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
    x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
    input_shape = (img_rows, img_cols, 1)

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

In [35]:

```
# Noise 0 to 4.0

scales = [0, .1, .5, 1.0, 2.0, 4.0]
train_acc = []
test_acc = []

batch_size = 128
num_classes = 10
epochs = 12

# convert class vectors to binary class matrices
y_train = tf.keras.utils.to_categorical(y_train, num_classes)
y_test = tf.keras.utils.to_categorical(y_test, num_classes)


for scale in scales:
    x_train_noise = x_train + np.random.normal(scale = scale, size=x_train.shap
    x_test_noise = x_test + np.random.normal(scale = scale, size=x_test.shape)

    model = Sequential()
    model.add(Conv2D(32, kernel_size=(3, 3),
                     activation='relu',
                     input_shape=input_shape))
    model.add(Conv2D(64, (3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))
    model.add(Flatten())
    model.add(Dense(128, activation='relu'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

    model.compile(loss=keras.losses.categorical_crossentropy,
                  optimizer=tf.keras.optimizers.Adadelta(learning_rate = 0.02),
                  metrics=['accuracy'])

    history = model.fit(x_train_noise, y_train,
                        batch_size = batch_size,
                        epochs = epochs,
                        verbose = 1,
                        validation_data = (x_test_noise, y_test))
```

```
    score = model.evaluate(x_test_noise, y_test, verbose=0)

    train_acc.append(history.history['accuracy'][-1])
    test_acc.append(score[1])
```

```
Epoch 1/12
  4/469 [..............................] - ETA: 8s - loss: 2.3186 - accuracy:
0.0664
2022-04-16 16:25:12.530003: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 1.1335 - accuracy:
0.6622
2022-04-16 16:25:19.319002: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - 8s 16ms/step - loss: 1.1335 - accur
acy: 0.6622 - val_loss: 0.3828 - val_accuracy: 0.8912
Epoch 2/12
469/469 [==============================] - 7s 16ms/step - loss: 0.4369 - accur
acy: 0.8701 - val_loss: 0.2805 - val_accuracy: 0.9201
Epoch 3/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3508 - accur
acy: 0.8972 - val_loss: 0.2400 - val_accuracy: 0.9308
Epoch 4/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3048 - accur
acy: 0.9115 - val_loss: 0.2093 - val_accuracy: 0.9375
Epoch 5/12
469/469 [==============================] - 7s 16ms/step - loss: 0.2722 - accur
acy: 0.9202 - val_loss: 0.1857 - val_accuracy: 0.9452
Epoch 6/12
469/469 [==============================] - 7s 16ms/step - loss: 0.2442 - accur
acy: 0.9286 - val_loss: 0.1661 - val_accuracy: 0.9505
Epoch 7/12
469/469 [==============================] - 7s 16ms/step - loss: 0.2260 - accur
acy: 0.9337 - val_loss: 0.1526 - val_accuracy: 0.9558
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 0.2084 - accur
acy: 0.9390 - val_loss: 0.1386 - val_accuracy: 0.9604
Epoch 9/12
469/469 [==============================] - 7s 16ms/step - loss: 0.1888 - accur
acy: 0.9433 - val_loss: 0.1298 - val_accuracy: 0.9621
Epoch 10/12
469/469 [==============================] - 7s 16ms/step - loss: 0.1783 - accur
acy: 0.9472 - val_loss: 0.1196 - val_accuracy: 0.9645
Epoch 11/12
469/469 [==============================] - 7s 16ms/step - loss: 0.1681 - accur
acy: 0.9509 - val_loss: 0.1119 - val_accuracy: 0.9662
Epoch 12/12
469/469 [==============================] - 7s 16ms/step - loss: 0.1566 - accur
acy: 0.9548 - val_loss: 0.1058 - val_accuracy: 0.9685
Epoch 1/12
  5/469 [..............................] - ETA: 7s - loss: 2.3132 - accuracy:
0.0906
2022-04-16 16:26:44.167334: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 1.1695 - accuracy:
0.6475
2022-04-16 16:26:51.095922: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 8s 16ms/step - loss: 1.1695 - accur
acy: 0.6475 - val_loss: 0.3950 - val_accuracy: 0.8915
Epoch 2/12
469/469 [==============================] - 8s 16ms/step - loss: 0.4513 - accur
acy: 0.8668 - val_loss: 0.2965 - val_accuracy: 0.9160
Epoch 3/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3676 - accur
acy: 0.8922 - val_loss: 0.2506 - val_accuracy: 0.9268
Epoch 4/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3187 - accur
acy: 0.9068 - val_loss: 0.2184 - val_accuracy: 0.9338
Epoch 5/12
469/469 [==============================] - 8s 16ms/step - loss: 0.2876 - accur
acy: 0.9159 - val_loss: 0.2008 - val_accuracy: 0.9397
Epoch 6/12
469/469 [==============================] - 8s 16ms/step - loss: 0.2636 - accur
acy: 0.9222 - val_loss: 0.1831 - val_accuracy: 0.9451
Epoch 7/12
469/469 [==============================] - 8s 17ms/step - loss: 0.2405 - accur
acy: 0.9293 - val_loss: 0.1624 - val_accuracy: 0.9522
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 0.2209 - accur
acy: 0.9342 - val_loss: 0.1518 - val_accuracy: 0.9547
Epoch 9/12
469/469 [==============================] - 8s 16ms/step - loss: 0.2056 - accur
acy: 0.9405 - val_loss: 0.1406 - val_accuracy: 0.9591
Epoch 10/12
469/469 [==============================] - 8s 17ms/step - loss: 0.1897 - accur
acy: 0.9439 - val_loss: 0.1302 - val_accuracy: 0.9607
Epoch 11/12
469/469 [==============================] - 8s 16ms/step - loss: 0.1763 - accur
acy: 0.9488 - val_loss: 0.1201 - val_accuracy: 0.9632
Epoch 12/12
469/469 [==============================] - 8s 16ms/step - loss: 0.1662 - accur
acy: 0.9512 - val_loss: 0.1116 - val_accuracy: 0.9669
Epoch 1/12
  4/469 [..............................] - ETA: 8s - loss: 2.3314 - accuracy:
0.0879
2022-04-16 16:28:18.812682: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 1.5199 - accuracy:
0.5147
2022-04-16 16:28:25.821277: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 8s 16ms/step - loss: 1.5199 - accur
acy: 0.5147 - val_loss: 0.6070 - val_accuracy: 0.8233
Epoch 2/12
469/469 [==============================] - 8s 17ms/step - loss: 0.6624 - accur
acy: 0.7956 - val_loss: 0.4572 - val_accuracy: 0.8593
Epoch 3/12
469/469 [==============================] - 8s 17ms/step - loss: 0.5601 - accur
acy: 0.8264 - val_loss: 0.4132 - val_accuracy: 0.8724
Epoch 4/12
469/469 [==============================] - 8s 17ms/step - loss: 0.5127 - accur
acy: 0.8417 - val_loss: 0.3874 - val_accuracy: 0.8817
Epoch 5/12
469/469 [==============================] - 8s 17ms/step - loss: 0.4790 - accur
acy: 0.8527 - val_loss: 0.3595 - val_accuracy: 0.8878
Epoch 6/12
469/469 [==============================] - 8s 16ms/step - loss: 0.4517 - accur
acy: 0.8598 - val_loss: 0.3421 - val_accuracy: 0.8938
Epoch 7/12
469/469 [==============================] - 7s 16ms/step - loss: 0.4234 - accur
acy: 0.8696 - val_loss: 0.3196 - val_accuracy: 0.9011
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 0.4033 - accur
acy: 0.8757 - val_loss: 0.3027 - val_accuracy: 0.9076
Epoch 9/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3829 - accur
acy: 0.8815 - val_loss: 0.2861 - val_accuracy: 0.9114
Epoch 10/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3654 - accur
acy: 0.8872 - val_loss: 0.2709 - val_accuracy: 0.9165
Epoch 11/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3462 - accur
acy: 0.8928 - val_loss: 0.2615 - val_accuracy: 0.9196
Epoch 12/12
469/469 [==============================] - 7s 16ms/step - loss: 0.3301 - accur
acy: 0.8986 - val_loss: 0.2459 - val_accuracy: 0.9247
Epoch 1/12
  5/469 [..............................] - ETA: 7s - loss: 2.3436 - accuracy:
0.1047
2022-04-16 16:29:53.539605: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
468/469 [============================>.] - ETA: 0s - loss: 1.9407 - accuracy:
0.3327
2022-04-16 16:30:00.331350: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

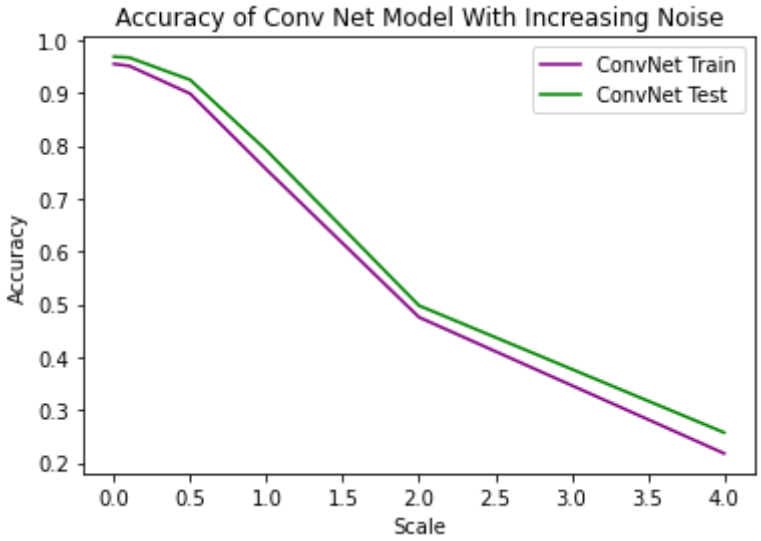
```
469/469 [==============================] - 8s 16ms/step - loss: 1.9401 - accur
acy: 0.3330 - val_loss: 1.1473 - val_accuracy: 0.6779
Epoch 2/12
469/469 [==============================] - 7s 16ms/step - loss: 1.1109 - accur
acy: 0.6371 - val_loss: 0.8459 - val_accuracy: 0.7333
Epoch 3/12
469/469 [==============================] - 7s 16ms/step - loss: 0.9684 - accur
acy: 0.6820 - val_loss: 0.8114 - val_accuracy: 0.7322
Epoch 4/12
469/469 [==============================] - 7s 16ms/step - loss: 0.9169 - accur
acy: 0.6983 - val_loss: 0.7691 - val_accuracy: 0.7492
Epoch 5/12
469/469 [==============================] - 7s 16ms/step - loss: 0.8857 - accur
acy: 0.7097 - val_loss: 0.7467 - val_accuracy: 0.7580
Epoch 6/12
469/469 [==============================] - 7s 16ms/step - loss: 0.8590 - accur
acy: 0.7185 - val_loss: 0.7333 - val_accuracy: 0.7635
Epoch 7/12
469/469 [==============================] - 8s 16ms/step - loss: 0.8407 - accur
acy: 0.7252 - val_loss: 0.7169 - val_accuracy: 0.7674
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 0.8165 - accur
acy: 0.7321 - val_loss: 0.6955 - val_accuracy: 0.7739
Epoch 9/12
469/469 [==============================] - 7s 16ms/step - loss: 0.7977 - accur
acy: 0.7384 - val_loss: 0.6877 - val_accuracy: 0.7788
Epoch 10/12
469/469 [==============================] - 7s 16ms/step - loss: 0.7792 - accur
acy: 0.7456 - val_loss: 0.6781 - val_accuracy: 0.7796
Epoch 11/12
469/469 [==============================] - 7s 16ms/step - loss: 0.7649 - accur
acy: 0.7497 - val_loss: 0.6571 - val_accuracy: 0.7868
Epoch 12/12
469/469 [==============================] - 7s 16ms/step - loss: 0.7515 - accur
acy: 0.7549 - val_loss: 0.6456 - val_accuracy: 0.7913
Epoch 1/12
  5/469 [..............................] - ETA: 7s - loss: 2.4682 - accuracy:
0.0922
2022-04-16 16:31:25.547726: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.2926 - accuracy:
0.1303
2022-04-16 16:31:32.258375: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 8s 16ms/step - loss: 2.2926 - accur
acy: 0.1303 - val_loss: 2.2021 - val_accuracy: 0.2504
Epoch 2/12
469/469 [==============================] - 7s 15ms/step - loss: 2.0575 - accur
acy: 0.2728 - val_loss: 1.7545 - val_accuracy: 0.4401
Epoch 3/12
469/469 [==============================] - 7s 16ms/step - loss: 1.7750 - accur
acy: 0.3840 - val_loss: 1.5797 - val_accuracy: 0.4649
Epoch 4/12
469/469 [==============================] - 8s 16ms/step - loss: 1.6762 - accur
acy: 0.4217 - val_loss: 1.5322 - val_accuracy: 0.4781
Epoch 5/12
469/469 [==============================] - 7s 16ms/step - loss: 1.6387 - accur
acy: 0.4365 - val_loss: 1.5031 - val_accuracy: 0.4869
Epoch 6/12
469/469 [==============================] - 7s 16ms/step - loss: 1.6112 - accur
acy: 0.4470 - val_loss: 1.4892 - val_accuracy: 0.4910
Epoch 7/12
469/469 [==============================] - 7s 16ms/step - loss: 1.5915 - accur
acy: 0.4535 - val_loss: 1.4791 - val_accuracy: 0.4923
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 1.5780 - accur
acy: 0.4600 - val_loss: 1.4752 - val_accuracy: 0.4944
Epoch 9/12
469/469 [==============================] - 7s 16ms/step - loss: 1.5648 - accur
acy: 0.4638 - val_loss: 1.4684 - val_accuracy: 0.4958
Epoch 10/12
469/469 [==============================] - 7s 16ms/step - loss: 1.5518 - accur
acy: 0.4680 - val_loss: 1.4599 - val_accuracy: 0.4972
Epoch 11/12
469/469 [==============================] - 8s 16ms/step - loss: 1.5428 - accur
acy: 0.4724 - val_loss: 1.4551 - val_accuracy: 0.4995
Epoch 12/12
469/469 [==============================] - 7s 16ms/step - loss: 1.5318 - accur
acy: 0.4753 - val_loss: 1.4562 - val_accuracy: 0.4974
Epoch 1/12
  4/469 [..............................] - ETA: 8s - loss: 2.8334 - accuracy:
0.1016
2022-04-16 16:32:57.642449: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.3254 - accuracy:
0.1046
2022-04-16 16:33:05.028095: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 8s 17ms/step - loss: 2.3254 - accur
acy: 0.1046 - val_loss: 2.3014 - val_accuracy: 0.1159
Epoch 2/12
469/469 [==============================] - 7s 15ms/step - loss: 2.3029 - accur
acy: 0.1095 - val_loss: 2.3024 - val_accuracy: 0.1126
Epoch 3/12
469/469 [==============================] - 7s 16ms/step - loss: 2.3023 - accur
acy: 0.1100 - val_loss: 2.3020 - val_accuracy: 0.1131
Epoch 4/12
469/469 [==============================] - 7s 15ms/step - loss: 2.3021 - accur
acy: 0.1099 - val_loss: 2.3012 - val_accuracy: 0.1161
Epoch 5/12
469/469 [==============================] - 7s 16ms/step - loss: 2.3001 - accur
acy: 0.1120 - val_loss: 2.2982 - val_accuracy: 0.1242
Epoch 6/12
469/469 [==============================] - 8s 16ms/step - loss: 2.2953 - accur
acy: 0.1167 - val_loss: 2.2856 - val_accuracy: 0.1294
Epoch 7/12
469/469 [==============================] - 7s 16ms/step - loss: 2.2838 - accur
acy: 0.1324 - val_loss: 2.2635 - val_accuracy: 0.1711
Epoch 8/12
469/469 [==============================] - 7s 16ms/step - loss: 2.2645 - accur
acy: 0.1521 - val_loss: 2.2375 - val_accuracy: 0.1925
Epoch 9/12
469/469 [==============================] - 7s 16ms/step - loss: 2.2396 - accur
acy: 0.1696 - val_loss: 2.1922 - val_accuracy: 0.2220
Epoch 10/12
469/469 [==============================] - 8s 16ms/step - loss: 2.2088 - accur
acy: 0.1894 - val_loss: 2.1569 - val_accuracy: 0.2413
Epoch 11/12
469/469 [==============================] - 8s 16ms/step - loss: 2.1826 - accur
acy: 0.2022 - val_loss: 2.1273 - val_accuracy: 0.2510
Epoch 12/12
469/469 [==============================] - 8s 16ms/step - loss: 2.1604 - accur
acy: 0.2174 - val_loss: 2.1153 - val_accuracy: 0.2570
```

In [37]:

```
plt.figure()
plt.plot(scales, train_acc, label = 'ConvNet Train', c = "purple")
plt.plot(scales, test_acc, label = 'ConvNet Test', c = "green")
plt.xlabel('Scale')
plt.ylabel('Accuracy')
plt.title('Accuracy of Conv Net Model With Increasing Noise')
plt.legend()
plt.show()
```



In [ ]:
```
perceptron_test =
perceptron_train =
```