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 [1]:

```
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 [2]:

```
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 [5]:

```
# 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 [6]:

```
# 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 = 0.01),
                  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
  5/469 [..............................] - ETA: 6s - loss: 2.3069 - accuracy:
0.0953
2022-04-18 10:49:21.188119: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 1.6304 - accuracy:
0.5076
2022-04-18 10:49:27.253988: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - 7s 14ms/step - loss: 1.6304 - accur
acy: 0.5076 - val_loss: 0.6424 - val_accuracy: 0.8570
Epoch 2/12
469/469 [==============================] - 6s 14ms/step - loss: 0.6442 - accur
acy: 0.8061 - val_loss: 0.3796 - val_accuracy: 0.8956
Epoch 3/12
469/469 [==============================] - 7s 14ms/step - loss: 0.4800 - accur
acy: 0.8580 - val_loss: 0.3168 - val_accuracy: 0.9101
Epoch 4/12
469/469 [==============================] - 6s 14ms/step - loss: 0.4143 - accur
acy: 0.8771 - val_loss: 0.2860 - val_accuracy: 0.9157
Epoch 5/12
469/469 [==============================] - 6s 14ms/step - loss: 0.3709 - accur
acy: 0.8901 - val_loss: 0.2606 - val_accuracy: 0.9230
Epoch 6/12
469/469 [==============================] - 7s 14ms/step - loss: 0.3409 - accur
acy: 0.8998 - val_loss: 0.2403 - val_accuracy: 0.9277
Epoch 7/12
469/469 [==============================] - 7s 14ms/step - loss: 0.3176 - accur
acy: 0.9065 - val_loss: 0.2258 - val_accuracy: 0.9312
Epoch 8/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2980 - accur
acy: 0.9123 - val_loss: 0.2106 - val_accuracy: 0.9362
Epoch 9/12
469/469 [==============================] - 7s 15ms/step - loss: 0.2796 - accur
acy: 0.9178 - val_loss: 0.1997 - val_accuracy: 0.9388
Epoch 10/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2671 - accur
acy: 0.9216 - val_loss: 0.1894 - val_accuracy: 0.9416
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2537 - accur
acy: 0.9253 - val_loss: 0.1819 - val_accuracy: 0.9432
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2423 - accur
acy: 0.9285 - val_loss: 0.1730 - val_accuracy: 0.9482
Epoch 1/12
  5/469 [..............................] - ETA: 5s - loss: 2.2987 - accuracy:
0.1203
2022-04-18 10:50:41.642099: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 1.6952 - accuracy:
0.4782
2022-04-18 10:50:47.678378: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 7s 14ms/step - loss: 1.6952 - accur
acy: 0.4782 - val_loss: 0.6908 - val_accuracy: 0.8542
Epoch 2/12
469/469 [==============================] - 6s 14ms/step - loss: 0.6656 - accur
acy: 0.8028 - val_loss: 0.3930 - val_accuracy: 0.8924
Epoch 3/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4891 - accur
acy: 0.8554 - val_loss: 0.3293 - val_accuracy: 0.9071
Epoch 4/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4218 - accur
acy: 0.8752 - val_loss: 0.2974 - val_accuracy: 0.9136
Epoch 5/12
469/469 [==============================] - 6s 13ms/step - loss: 0.3822 - accur
acy: 0.8874 - val_loss: 0.2719 - val_accuracy: 0.9204
Epoch 6/12
469/469 [==============================] - 6s 14ms/step - loss: 0.3486 - accur
acy: 0.8971 - val_loss: 0.2512 - val_accuracy: 0.9268
Epoch 7/12
469/469 [==============================] - 6s 13ms/step - loss: 0.3282 - accur
acy: 0.9033 - val_loss: 0.2368 - val_accuracy: 0.9301
Epoch 8/12
469/469 [==============================] - 6s 13ms/step - loss: 0.3051 - accur
acy: 0.9094 - val_loss: 0.2242 - val_accuracy: 0.9346
Epoch 9/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2914 - accur
acy: 0.9148 - val_loss: 0.2116 - val_accuracy: 0.9351
Epoch 10/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2757 - accur
acy: 0.9195 - val_loss: 0.2005 - val_accuracy: 0.9391
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2607 - accur
acy: 0.9231 - val_loss: 0.1904 - val_accuracy: 0.9429
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 0.2542 - accur
acy: 0.9258 - val_loss: 0.1832 - val_accuracy: 0.9454
Epoch 1/12
  9/469 [..............................] - ETA: 5s - loss: 2.3259 - accuracy:
0.0955
```

```
2022-04-18 10:52:00.069240: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
468/469 [============================>.] - ETA: 0s - loss: 2.0681 - accuracy:
0.3078
```

```
2022-04-18 10:52:06.104674: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 7s 14ms/step - loss: 2.0674 - accur
acy: 0.3082 - val_loss: 1.4403 - val_accuracy: 0.7127
Epoch 2/12
469/469 [==============================] - 6s 14ms/step - loss: 1.0873 - accur
acy: 0.6779 - val_loss: 0.6283 - val_accuracy: 0.8281
Epoch 3/12
469/469 [==============================] - 6s 14ms/step - loss: 0.7272 - accur
acy: 0.7751 - val_loss: 0.5045 - val_accuracy: 0.8507
Epoch 4/12
469/469 [==============================] - 7s 14ms/step - loss: 0.6251 - accur
acy: 0.8077 - val_loss: 0.4532 - val_accuracy: 0.8628
Epoch 5/12
469/469 [==============================] - 6s 13ms/step - loss: 0.5723 - accur
acy: 0.8235 - val_loss: 0.4248 - val_accuracy: 0.8684
Epoch 6/12
469/469 [==============================] - 6s 13ms/step - loss: 0.5382 - accur
acy: 0.8350 - val_loss: 0.4065 - val_accuracy: 0.8737
Epoch 7/12
469/469 [==============================] - 6s 13ms/step - loss: 0.5106 - accur
acy: 0.8424 - val_loss: 0.3891 - val_accuracy: 0.8809
Epoch 8/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4897 - accur
acy: 0.8501 - val_loss: 0.3747 - val_accuracy: 0.8839
Epoch 9/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4753 - accur
acy: 0.8540 - val_loss: 0.3659 - val_accuracy: 0.8880
Epoch 10/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4596 - accur
acy: 0.8580 - val_loss: 0.3515 - val_accuracy: 0.8909
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4424 - accur
acy: 0.8642 - val_loss: 0.3410 - val_accuracy: 0.8946
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 0.4308 - accur
acy: 0.8676 - val_loss: 0.3323 - val_accuracy: 0.8947
Epoch 1/12
  1/469 [..............................] - ETA: 2:33 - loss: 2.4331 - accurac
y: 0.0547
```

```
2022-04-18 10:53:18.931089: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - ETA: 0s - loss: 2.2436 - accuracy:
0.1766
```

```
2022-04-18 10:53:25.142493: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 7s 14ms/step - loss: 2.2436 - accur
acy: 0.1766 - val_loss: 2.0644 - val_accuracy: 0.4639
Epoch 2/12
469/469 [==============================] - 7s 14ms/step - loss: 1.8378 - accur
acy: 0.4078 - val_loss: 1.3590 - val_accuracy: 0.6714
Epoch 3/12
469/469 [==============================] - 6s 14ms/step - loss: 1.3106 - accur
acy: 0.5781 - val_loss: 0.9818 - val_accuracy: 0.7144
Epoch 4/12
469/469 [==============================] - 6s 13ms/step - loss: 1.0927 - accur
acy: 0.6425 - val_loss: 0.8732 - val_accuracy: 0.7305
Epoch 5/12
469/469 [==============================] - 6s 14ms/step - loss: 1.0050 - accur
acy: 0.6714 - val_loss: 0.8259 - val_accuracy: 0.7371
Epoch 6/12
469/469 [==============================] - 6s 13ms/step - loss: 0.9566 - accur
acy: 0.6831 - val_loss: 0.8007 - val_accuracy: 0.7444
Epoch 7/12
469/469 [==============================] - 6s 13ms/step - loss: 0.9303 - accur
acy: 0.6920 - val_loss: 0.7813 - val_accuracy: 0.7494
Epoch 8/12
469/469 [==============================] - 7s 14ms/step - loss: 0.9085 - accur
acy: 0.7008 - val_loss: 0.7702 - val_accuracy: 0.7537
Epoch 9/12
469/469 [==============================] - 8s 18ms/step - loss: 0.8924 - accur
acy: 0.7057 - val_loss: 0.7612 - val_accuracy: 0.7541
Epoch 10/12
469/469 [==============================] - 6s 13ms/step - loss: 0.8812 - accur
acy: 0.7091 - val_loss: 0.7536 - val_accuracy: 0.7544
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 0.8664 - accur
acy: 0.7154 - val_loss: 0.7459 - val_accuracy: 0.7571
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 0.8579 - accur
acy: 0.7184 - val_loss: 0.7389 - val_accuracy: 0.7588
Epoch 1/12
  5/469 [..............................] - ETA: 6s - loss: 2.5829 - accuracy:
0.0953
```

```
2022-04-18 10:54:40.582033: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - ETA: 0s - loss: 2.3186 - accuracy:
0.1150
```

```
2022-04-18 10:54:46.497946: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 7s 13ms/step - loss: 2.3186 - accur
acy: 0.1150 - val_loss: 2.2905 - val_accuracy: 0.1627
Epoch 2/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2744 - accur
acy: 0.1490 - val_loss: 2.2199 - val_accuracy: 0.2610
Epoch 3/12
469/469 [==============================] - 7s 14ms/step - loss: 2.1926 - accur
acy: 0.2057 - val_loss: 2.0516 - val_accuracy: 0.3384
Epoch 4/12
469/469 [==============================] - 6s 13ms/step - loss: 2.0334 - accur
acy: 0.2865 - val_loss: 1.8456 - val_accuracy: 0.4126
Epoch 5/12
469/469 [==============================] - 6s 13ms/step - loss: 1.8794 - accur
acy: 0.3438 - val_loss: 1.6946 - val_accuracy: 0.4556
Epoch 6/12
469/469 [==============================] - 6s 13ms/step - loss: 1.7756 - accur
acy: 0.3869 - val_loss: 1.6085 - val_accuracy: 0.4638
Epoch 7/12
469/469 [==============================] - 6s 13ms/step - loss: 1.7115 - accur
acy: 0.4075 - val_loss: 1.5562 - val_accuracy: 0.4785
Epoch 8/12
469/469 [==============================] - 7s 14ms/step - loss: 1.6717 - accur
acy: 0.4225 - val_loss: 1.5262 - val_accuracy: 0.4837
Epoch 9/12
469/469 [==============================] - 7s 14ms/step - loss: 1.6423 - accur
acy: 0.4326 - val_loss: 1.5012 - val_accuracy: 0.4892
Epoch 10/12
469/469 [==============================] - 6s 14ms/step - loss: 1.6245 - accur
acy: 0.4420 - val_loss: 1.4944 - val_accuracy: 0.4906
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 1.6167 - accur
acy: 0.4439 - val_loss: 1.4770 - val_accuracy: 0.4993
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 1.6007 - accur
acy: 0.4518 - val_loss: 1.4743 - val_accuracy: 0.4970
Epoch 1/12
  1/469 [..............................] - ETA: 2:23 - loss: 3.4353 - accurac
y: 0.1250
```

```
2022-04-18 10:56:00.008752: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

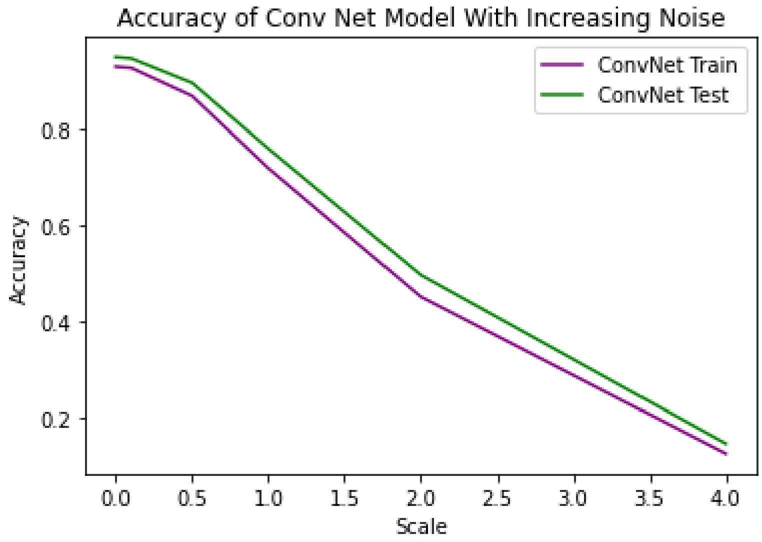
```
469/469 [==============================] - ETA: 0s - loss: 2.3599 - accuracy:
0.1053
```

```
2022-04-18 10:56:06.107971: I tensorflow/core/grappler/optimizers/custom_graph
_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 7s 14ms/step - loss: 2.3599 - accur
acy: 0.1053 - val_loss: 2.3026 - val_accuracy: 0.1126
Epoch 2/12
469/469 [==============================] - 8s 16ms/step - loss: 2.3039 - accur
acy: 0.1110 - val_loss: 2.3025 - val_accuracy: 0.1117
Epoch 3/12
469/469 [==============================] - 6s 14ms/step - loss: 2.3027 - accur
acy: 0.1101 - val_loss: 2.3023 - val_accuracy: 0.1137
Epoch 4/12
469/469 [==============================] - 6s 14ms/step - loss: 2.3027 - accur
acy: 0.1111 - val_loss: 2.3022 - val_accuracy: 0.1133
Epoch 5/12
469/469 [==============================] - 6s 13ms/step - loss: 2.3019 - accur
acy: 0.1130 - val_loss: 2.3010 - val_accuracy: 0.1139
Epoch 6/12
469/469 [==============================] - 6s 13ms/step - loss: 2.3019 - accur
acy: 0.1126 - val_loss: 2.3015 - val_accuracy: 0.1144
Epoch 7/12
469/469 [==============================] - 6s 13ms/step - loss: 2.3004 - accur
acy: 0.1135 - val_loss: 2.2996 - val_accuracy: 0.1163
Epoch 8/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2995 - accur
acy: 0.1162 - val_loss: 2.2978 - val_accuracy: 0.1208
Epoch 9/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2979 - accur
acy: 0.1166 - val_loss: 2.2955 - val_accuracy: 0.1220
Epoch 10/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2948 - accur
acy: 0.1179 - val_loss: 2.2907 - val_accuracy: 0.1353
Epoch 11/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2913 - accur
acy: 0.1227 - val_loss: 2.2862 - val_accuracy: 0.1367
Epoch 12/12
469/469 [==============================] - 6s 13ms/step - loss: 2.2869 - accur
acy: 0.1272 - val_loss: 2.2773 - val_accuracy: 0.1478
```

In [7]:

```
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()
```

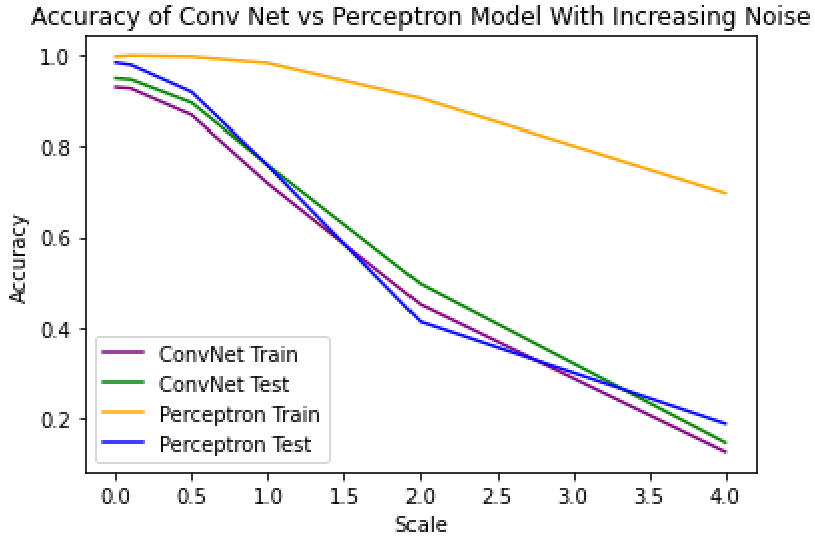


In [8]:

```
perceptron_test = [0.9826000332832336,
0.9778000712394714,
 0.9180000424385071,
 0.7573000192642212,
 0.4139000177383423,
 0.1894000236034393]
perceptron_train = [0.9956833720207214,
0.9980166554450989,
 0.9956666827201843,
 0.9816666841506958,
 0.9045000076293945,
 0.6969166994094849]
```

In [9]:

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



The Perceptron training model remained the best performing model across all scales. Initially, at scales below 1.0, the Perceptron test model outperformed Conv Net. However, with scales greater than about 1.5, the Conv Net models outperformed hte Perceptron test model, but still did not outperform the Perceptron training model.

In [ ]: