In [1]:

```
# Credits: https://github.com/keras-team/keras/blob/master/examples/mnist_cnn.py


from __future__ import print_function
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 keras import backend as K

batch_size = 128
num_classes = 10
epochs = 12

# input image dimensions
img_rows, img_cols = 28, 28

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

if K.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')

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

```
Using TensorFlow backend.
```

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

Architecture 1: Conlayers-2

kernel size 3*3

In [2]:

```
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=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
WARNING:tensorflow:From C:\Users\Public\Anacon
da3\lib\site-packages\tensorflow\python\framew
```

```
ork\op_def_library.py:263: colocate_with (from
 tensorflow.python.framework.ops) is deprecate
d and will be removed in a future version.
Instructions for updating:
Colocations handled automatically by placer.
WARNING:tensorflow:From C:\Users\Public\Anacon
da3\lib\site-packages\keras\backend\tensorflow
_backend.py:3445: calling dropout (from tensor
flow.python.ops.nn_ops) with keep_prob is depr
ecated and will be removed in a future version
.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate
 should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From C:\Users\Public\Anacon
da3\lib\site-packages\tensorflow\python\ops\ma
th_ops.py:3066: to_int32 (from tensorflow.pyth
on.ops.math_ops) is deprecated and will be rem
oved in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 60000 samples, validate on 10000 samp
les
Epoch 1/12
60000/60000 [==============================] -
 93s 2ms/step - loss: 0.2580 - acc: 0.9219 - v
al_loss: 0.0524 - val_acc: 0.9831
Epoch 2/12
60000/60000 [==============================] -
 98s 2ms/step - loss: 0.0852 - acc: 0.9745 - v
al_loss: 0.0391 - val_acc: 0.9864
Epoch 3/12
60000/60000 [==============================] -
 95s 2ms/step - loss: 0.0649 - acc: 0.9812 - v
al_loss: 0.0346 - val_acc: 0.9882
Epoch 4/12
60000/60000 [==============================] -
```

```
 92s 2ms/step - loss: 0.0548 - acc: 0.9838 - v
al_loss: 0.0304 - val_acc: 0.9905
Epoch 5/12
60000/60000 [==============================] -
 89s 1ms/step - loss: 0.0463 - acc: 0.9860 - v
al_loss: 0.0308 - val_acc: 0.9893
Epoch 6/12
60000/60000 [==============================] -
 88s 1ms/step - loss: 0.0421 - acc: 0.9871 - v
al_loss: 0.0275 - val_acc: 0.9896
Epoch 7/12
60000/60000 [==============================] -
 89s 1ms/step - loss: 0.0388 - acc: 0.9886 - v
al_loss: 0.0276 - val_acc: 0.9904
Epoch 8/12
60000/60000 [==============================] -
 88s 1ms/step - loss: 0.0342 - acc: 0.9899 - v
al_loss: 0.0297 - val_acc: 0.9907
Epoch 9/12
60000/60000 [==============================] -
 89s 1ms/step - loss: 0.0312 - acc: 0.9908 - v
al_loss: 0.0254 - val_acc: 0.9915
Epoch 10/12
60000/60000 [==============================] -
 91s 2ms/step - loss: 0.0295 - acc: 0.9907 - v
al_loss: 0.0320 - val_acc: 0.9896
Epoch 11/12
60000/60000 [==============================] -
 91s 2ms/step - loss: 0.0266 - acc: 0.9918 - v
al_loss: 0.0276 - val_acc: 0.9914
Epoch 12/12
60000/60000 [==============================] -
 92s 2ms/step - loss: 0.0258 - acc: 0.9918 - v
al_loss: 0.0293 - val_acc: 0.9917
Test loss: 0.029326565258706888
Test accuracy: 0.9917
```

Architecture2: kernel 3*3 Conlayers 3

In [3]:

```
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(0.4))
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.4))
model.add(Flatten())
model.add(Dense(256, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Train on 60000 samples, validate on 10000 samp
les
Epoch 1/12
60000/60000 [==============================] -
 125s 2ms/step - loss: 0.2741 - acc: 0.9131 -
val_loss: 0.0524 - val_acc: 0.9829
Epoch 2/12
60000/60000 [==============================] -
 120s 2ms/step - loss: 0.0807 - acc: 0.9754 -
val_loss: 0.0339 - val_acc: 0.9883
Epoch 3/12
60000/60000 [==============================] -
 120s 2ms/step - loss: 0.0608 - acc: 0.9812 -
val_loss: 0.0272 - val_acc: 0.9911
Epoch 4/12
60000/60000 [==============================] -
 118s 2ms/step - loss: 0.0501 - acc: 0.9846 -
val_loss: 0.0254 - val_acc: 0.9915
Epoch 5/12
60000/60000 [==============================] -
 118s 2ms/step - loss: 0.0430 - acc: 0.9869 -
val_loss: 0.0225 - val_acc: 0.9919
Epoch 6/12
60000/60000 [==============================] -
 120s 2ms/step - loss: 0.0403 - acc: 0.9877 -
val_loss: 0.0221 - val_acc: 0.9921
Epoch 7/12
60000/60000 [==============================] -
 119s 2ms/step - loss: 0.0357 - acc: 0.9892 -
val_loss: 0.0199 - val_acc: 0.9932
Epoch 8/12
60000/60000 [==============================] -
 121s 2ms/step - loss: 0.0339 - acc: 0.9894 -
val_loss: 0.0200 - val_acc: 0.9934
Epoch 9/12
60000/60000 [==============================] -
 119s 2ms/step - loss: 0.0307 - acc: 0.9903 -
```

```
val_loss: 0.0180 - val_acc: 0.9942
Epoch 10/12
60000/60000 [==============================] -
 116s 2ms/step - loss: 0.0291 - acc: 0.9911 -
val_loss: 0.0186 - val_acc: 0.9938
Epoch 11/12
60000/60000 [==============================] -
 117s 2ms/step - loss: 0.0265 - acc: 0.9916 -
val_loss: 0.0198 - val_acc: 0.9932
Epoch 12/12
60000/60000 [==============================] -
 120s 2ms/step - loss: 0.0259 - acc: 0.9921 -
val_loss: 0.0171 - val_acc: 0.9941
Test loss: 0.017080856872715048
Test accuracy: 0.9941
```

Architecture3: kernel 3*3 Conlayers 3 droupout 0.25 and batch normalization

In [4]:

```
from keras.layers.normalization import BatchNormalization


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=(3, 3)))
model.add(Dropout(0.25))
model.add(BatchNormalization())

model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(3, 3)))
model.add(Dropout(0.25))
model.add(BatchNormalization())

model.add(Flatten())
model.add(Dense(256, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

model.fit(x_train, y_train,
```

```
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Train on 60000 samples, validate on 10000 samp
les
Epoch 1/12
60000/60000 [==============================] -
 107s 2ms/step - loss: 0.2693 - acc: 0.9150 -
val_loss: 0.0537 - val_acc: 0.9830
Epoch 2/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0773 - acc: 0.9764 -
val_loss: 0.0297 - val_acc: 0.9914
Epoch 3/12
60000/60000 [==============================] -
 105s 2ms/step - loss: 0.0582 - acc: 0.9826 -
val_loss: 0.0282 - val_acc: 0.9910
Epoch 4/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0445 - acc: 0.9860 -
val_loss: 0.0386 - val_acc: 0.9865
Epoch 5/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0407 - acc: 0.9879 -
val_loss: 0.0264 - val_acc: 0.9923
Epoch 6/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0369 - acc: 0.9885 -
val_loss: 0.0209 - val_acc: 0.9927
Epoch 7/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0343 - acc: 0.9891 -
```

```
val_loss: 0.0211 - val_acc: 0.9942
Epoch 8/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0307 - acc: 0.9909 -
val_loss: 0.0188 - val_acc: 0.9942
Epoch 9/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0270 - acc: 0.9919 -
val_loss: 0.0200 - val_acc: 0.9941
Epoch 10/12
60000/60000 [==============================] -
 105s 2ms/step - loss: 0.0280 - acc: 0.9915 -
val_loss: 0.0211 - val_acc: 0.9934
Epoch 11/12
60000/60000 [==============================] -
 107s 2ms/step - loss: 0.0278 - acc: 0.9913 -
val_loss: 0.0216 - val_acc: 0.9934
Epoch 12/12
60000/60000 [==============================] -
 104s 2ms/step - loss: 0.0240 - acc: 0.9927 -
val_loss: 0.0199 - val_acc: 0.9941
Test loss: 0.01993270480447845
Test accuracy: 0.9941
```

Architecture 4: kernel 5*5 Conlayers 5 batch normalization

In [14]:

```
from keras.layers.normalization import BatchNormalization


model = Sequential()
model.add(Conv2D(16, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))

model.add(Conv2D(32, (5, 5), padding='same',strides=1,activat
ion='relu'))
model.add(MaxPooling2D(pool_size=(2, 2),strides=None, padding
='same', data_format=None))
model.add(BatchNormalization())

model.add(Conv2D(64, (5, 5), padding='same',activation='relu'
))
model.add(MaxPooling2D(pool_size=(2, 2),strides=1, padding='s
ame', data_format=None))
model.add(Dropout(0.25))
model.add(BatchNormalization())

model.add(Conv2D(128, (5, 5),padding='same',strides=1, activa
tion='relu'))
model.add(MaxPooling2D(pool_size=(2, 2),strides=1, padding='s
ame', data_format=None))
model.add(Dropout(0.25))
model.add(BatchNormalization())
```

```
model.add(Conv2D(256, (5, 5),activation='relu'))
model.add(Dropout(0.4))
model.add(BatchNormalization())

model.add(Flatten())
model.add(Dense(512, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
WARNING:tensorflow:From C:\Users\Public\Anacon
da3\lib\site-packages\tensorflow\python\ops\ma
th_ops.py:3066: to_int32 (from tensorflow.pyth
on.ops.math_ops) is deprecated and will be rem
oved in a future version.
Instructions for updating:
Use tf.cast instead.
Train on 60000 samples, validate on 10000 samp
les
Epoch 1/12
60000/60000 [==============================] -
 735s 12ms/step - loss: 0.4790 - acc: 0.9320 -
 val_loss: 0.0606 - val_acc: 0.9864
Epoch 2/12
60000/60000 [==============================] -
```

```
 733s 12ms/step - loss: 0.0751 - acc: 0.9815 -
 val_loss: 0.1089 - val_acc: 0.9766
Epoch 3/12
60000/60000 [==============================] -
 703s 12ms/step - loss: 0.0545 - acc: 0.9867 -
 val_loss: 0.0681 - val_acc: 0.9850
Epoch 4/12
60000/60000 [==============================] -
 706s 12ms/step - loss: 0.0432 - acc: 0.9892 -
 val_loss: 0.0295 - val_acc: 0.9933
Epoch 5/12
60000/60000 [==============================] -
 725s 12ms/step - loss: 0.0348 - acc: 0.9908 -
 val_loss: 0.0304 - val_acc: 0.9938
Epoch 6/12
60000/60000 [==============================] -
 720s 12ms/step - loss: 0.0299 - acc: 0.9924 -
 val_loss: 0.0428 - val_acc: 0.9900
Epoch 7/12
60000/60000 [==============================] -
 724s 12ms/step - loss: 0.0265 - acc: 0.9928 -
 val_loss: 0.0239 - val_acc: 0.9949
Epoch 8/12
60000/60000 [==============================] -
 765s 13ms/step - loss: 0.0251 - acc: 0.9934 -
 val_loss: 0.0256 - val_acc: 0.9948
Epoch 9/12
60000/60000 [==============================] -
 763s 13ms/step - loss: 0.0201 - acc: 0.9948 -
 val_loss: 0.0315 - val_acc: 0.9939
Epoch 10/12
60000/60000 [==============================] -
 761s 13ms/step - loss: 0.0193 - acc: 0.9951 -
 val_loss: 0.0244 - val_acc: 0.9948
Epoch 11/12
60000/60000 [==============================] -
 768s 13ms/step - loss: 0.0173 - acc: 0.9961 -
```

```
 val_loss: 0.0265 - val_acc: 0.9950
Epoch 12/12
60000/60000 [==============================] -
 769s 13ms/step - loss: 0.0162 - acc: 0.9961 -
 val_loss: 0.0284 - val_acc: 0.9954
Test loss: 0.02835287011177452
Test accuracy: 0.9954
```

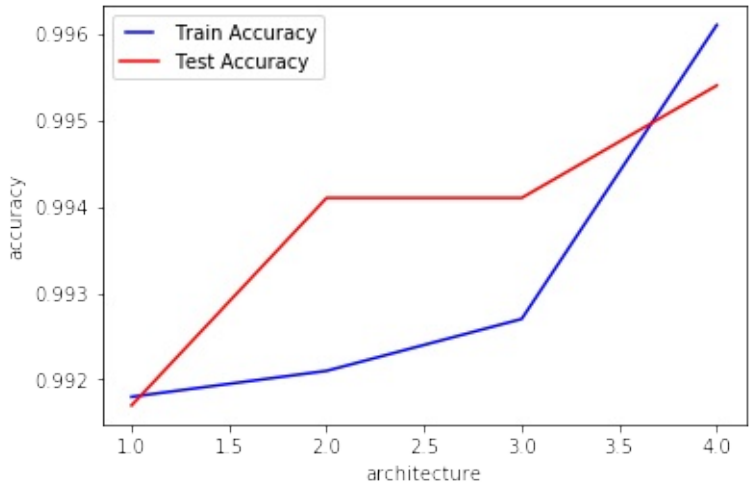
In [4]:

```
#plotting error plots for all the models

values =[1,2,3,4]
train_results=[0.9918,0.9921,0.9927,0.9961]
test_results=[0.9917,0.9941,0.9941,0.9954]

import matplotlib.pyplot as plt
from matplotlib.legend_handler import HandlerLine2D
line1, = plt.plot(values, train_results, 'b', label="Train Ac
curacy")
line2, = plt.plot(values, test_results, 'r', label="Test Accu
racy")

plt.legend(handler_map={line1: HandlerLine2D(numpoints=2)})
plt.ylabel("accuracy")
plt.xlabel("architecture")
plt.show()
```


Train Accuracy
Test Accuracy
0.996
0.995
0.994
0.993
0.992
accuracy
1.0
1.5
2.0
2.5
3.0
3.5
4.0
architecture

1.we can observe that for architecture 3 we get best results even model 2 give good results but among them model 3 is best .

2.For model 4 and model 1, we could observe that test accuracy is more train accuracy which indicates the accuracy for unseen data is more than the train data which is not common.

conclusions

In [1]:

```
from prettytable import PrettyTable

#If you get a ModuleNotFoundError error , install prettytable
 using: pip3 install prettytable

x = PrettyTable()
x.field_names = ["CNN- architecture ", "convulution layers",
"kernel size",  "Regularization", "Train accuracy", "Test Acc
uracy"]

x.add_row(["Architecture 1", 2, "3*3", "Droupout", 0.9918, 0.
9917])
x.add_row(["Architecture 2", 3, "3*3", "Droupout", 0.9921, 0.
9941])
x.add_row(["Architecture 3", 3, "3*3", "Batch", 0.9927, 0.994
1])
x.add_row(["Architecture 4", 5, "5*5", "Droupout+batch",0.996
1 ,0.9954 ])


print(x)
```

```
+--------------------+--------------------+---
----------+----------------+----------------+-
--------------+
| CNN- architecture  | convulution layers | ke
rnel size | Regularization | Train accuracy |
Test Accuracy |
+--------------------+--------------------+---
----------+----------------+----------------+-
```

```
--------------+
|   Architecture 1   |         2          |
  3*3     |    Droupout    |     0.9918     |
    0.9917    |
|   Architecture 2   |         3          |
  3*3     |    Droupout    |     0.9921     |
    0.9941    |
|   Architecture 3   |         3          |
  3*3     |     Batch      |     0.9927     |
    0.9941    |
|   Architecture 4   |         5          |
  5*5     | Droupout+batch |     0.9961     |
    0.9954    |
+--------------------+--------------------+---
----------+----------------+----------------+-
--------------+
```

In [ ]:

```
#We could observe with increase in kernel size as performance
 is increasing but it is taking longer time to execute
```