COURSE TITLE: SOFTWARE QUALITY ENGINEERING (2019-2023)

Project: Mnist Handwritten Digit Classification

TO

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MNIST Handwritten Digit Recognition

Introduction

Handwritten digits recognition could be a well-researched subarea among the sphere that's involved with learning models to differentiate pre-segmented written digits. it's one among the foremost necessary problems in knowledge mining, machine learning, pattern recognition together with several different disciplines of computer science .

The main application of machine learning strategies over the last decade has determined efficacious in conformist decisive systems that are competitor to human performance and which accomplish so much improved than manually written classical artificial intelligence systems employed in the beginnings of optical character recognition technology. However, not all options of these specific models are antecedently inspected. An excellent try of researcher in machine learning and data processing has been contrived to realize economical approaches for approximation of recognition from data.

In 21st century written digit communication has its own normal and most of the days in standard of living are being employed as means that of voice communication and recording the knowledge to be shared with individuals. One among the challenges in handwritten characters recognition entirely lies within the variation and distortion of handwritten listing as a result of distinct community could use various type of handwriting, and management to draw the similar pattern of the characters of their recognized script. Identification of digit from wherever best discriminating options are often extracted is one among the main tasks within the space of digit recognition system. To find such regions totally different quite region sampling techniques are employed in pattern recognition.

The challenge in written character recognition is principally caused by the big variation of individual writing styles. Hence, strong feature extraction is extremely important to boost the performance of a handwritten character recognition system. These days handwritten digit recognition has obtained heap of concentration in the area of pattern recognition system sowing to its application in various fields. In next days, character recognition system may function as a cornerstone to initiate paperless surroundings by digitizing and process existing paper documents.

MNIST Dataset

The **MNIST database** (*Modified National Institute of Standards and Technology database*) is a large database of handwritten digits that is commonly used for training various image processing systems. The database is also widely used for training and testing in the field of machine learning. It was created by "re-mixing" the samples from NIST's original datasets. The creators felt that since NIST's training dataset was taken from American Census Bureau employees, while the testing dataset was taken from American high school students, it was not well-suited for machine learning experiments. Furthermore, the black and white images from NIST were normalized to fit into a 28x28 pixel bounding box and anti-aliased, which introduced grayscale levels.

The MNIST database contains 60,000 training images and 10,000 testing images. Half of the training set and half of the test set were taken from NIST's training dataset, while the other half of the training set and the other half of the test set were taken from NIST's testing dataset.

Analysis of MNIST Data Set with FCN and CNN

The MNIST data set gives a maximum accuracy of 87% generally with algorithm including SVM, RF and Naïve Bayes. Two algorithms were tested with the dataset: Fully Convolutional Network and Convolutional Neural Network. The training and testing was done and CNN was found to have the highest accuracy of 98% approximately. Therefore it was used for the model. However, both were tested for results in GUI user based application as well. The detailed work is shown below:

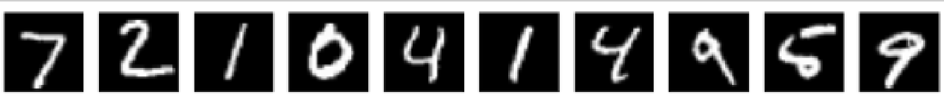
IMPORT DATA SET AND PREPROCESSING

In [2]:
```python
###1. Load Data and Split Data
from tensorflow import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers.core import Dense, Activation
from keras.utils import np_utils

import numpy as np
from tensorflow import keras
from tensorflow.keras import layers
from keras.datasets import mnist

(X_train, Y_train), (X_test, Y_test) = mnist.load_data()
```

In [3]:
```python
#preprocessing
import matplotlib.pyplot as plt
n = 10  # how many digits we will display
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(X_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
plt.close()
```



In [4]:
```python
print("Previous X_train shape: {} \nPrevious Y_train shape:{}".format(X_train.shape, Y_train.shape))
X_train = X_train.reshape(60000, 784)
X_test = X_test.reshape(10000, 784)
X_train = X_train.astype('float32')
X_test = X_test.astype('float32')
X_train /= 255
X_test /= 255
classes = 10
Y_train = np_utils.to_categorical(Y_train, classes)
Y_test = np_utils.to_categorical(Y_test, classes)
print("New X_train shape: {} \nNew Y_train shape:{}".format(X_train.shape, Y_train.shape))
```

```
Previous X_train shape: (60000, 28, 28)
Previous Y_train shape:(60000,)
New X_train shape: (60000, 784)
New Y_train shape:(60000, 10)
```

In [5]:
```python
#Setting up parameters
input_size = 784
batch_size = 200
hidden1 = 400
hidden2 = 20
epochs = 2
```

Recognition Through Fully Covulutional Network Model.

In [6]:

```
#Building FCN Model
###4.Build the model
model = Sequential()
model.add(Dense(hidden1, input_dim=input_size, activation='relu'))
# output = relu (dot (W, input) + bias)
model.add(Dense(hidden2, activation='relu'))
model.add(Dense(classes, activation='softmax'))

# Compilation
model.compile(loss='categorical_crossentropy',
    metrics=['accuracy'], optimizer='sgd')
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                (None, 400)               314000
_________________________________________________________________
dense_1 (Dense)              (None, 20)                8020
_________________________________________________________________
dense_2 (Dense)              (None, 10)                210
=================================================================
Total params: 322,230
Trainable params: 322,230
Non-trainable params: 0
_________________________________________________________________
```

In [7]:

```
#Training the model
# Fitting on Data
model.fit(X_train, Y_train, batch_size=batch_size, epochs=10, verbose=2)
###5.Test
```

```
Epoch 1/10
300/300 - 5s - loss: 1.5074 - accuracy: 0.6038
Epoch 2/10
300/300 - 2s - loss: 0.7047 - accuracy: 0.8234
Epoch 3/10
300/300 - 2s - loss: 0.5072 - accuracy: 0.8679
Epoch 4/10
300/300 - 2s - loss: 0.4235 - accuracy: 0.8858
Epoch 5/10
300/300 - 2s - loss: 0.3772 - accuracy: 0.8948
Epoch 6/10
300/300 - 2s - loss: 0.3470 - accuracy: 0.9022
Epoch 7/10
300/300 - 2s - loss: 0.3251 - accuracy: 0.9081
Epoch 8/10
300/300 - 2s - loss: 0.3076 - accuracy: 0.9123
Epoch 9/10
300/300 - 2s - loss: 0.2931 - accuracy: 0.9164
Epoch 10/10
300/300 - 2s - loss: 0.2807 - accuracy: 0.9197
```

Out[7]:

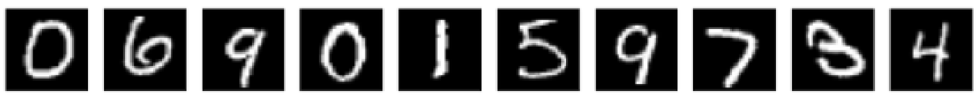
```
<keras.callbacks.History at 0x22592ec2e50>
```

In [8]:

```python
#Testing the model
score = model.evaluate(X_test, Y_test, verbose=1)
print('\n''Test accuracy:', score[1])
mask = range(10,20)
X_valid = X_test[mask]
y_pred = (model.predict(X_valid) > 0.5).astype("int32")
print(y_pred)
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(X_valid[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
plt.close()
model.save('C:\\Users\\Admin\\Downloads\\FCNN')
```

```
313/313 [==============================] - 1s 3ms/step - loss: 0.2656 - accuracy: 0.9228

Test accuracy: 0.9228000044822693
[[1 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 1 0 0 0]
 [0 0 0 0 0 0 0 0 0 1]
 [1 0 0 0 0 0 0 0 0 0]
 [0 1 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 1 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 1]
 [0 0 0 0 0 0 0 1 0 0]
 [0 0 0 1 0 0 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0]]
```



```
INFO:tensorflow:Assets written to: C:\Users\Admin\Downloads\FCNN\assets
```

Recognition Through Convulational Neural Network Model.

In [9]:

```
#CNN
#Prepare the data
# Model / data parameters
num_classes = 10
input_shape = (28, 28, 1)

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

# Scale images to the [0, 1] range
x_train = x_train.astype("float32") / 255
x_test = x_test.astype("float32") / 255
# Make sure images have shape (28, 28, 1)
x_train = np.expand_dims(x_train, -1)
x_test = np.expand_dims(x_test, -1)
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)

```

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

In [10]:

```
#Build Model CNN
model = keras.Sequential(
    [
        keras.Input(shape=input_shape),
        layers.Conv2D(32, kernel_size=(3, 3), activation="relu"),
        layers.MaxPooling2D(pool_size=(2, 2)),
        layers.Conv2D(64, kernel_size=(3, 3), activation="relu"),
        layers.MaxPooling2D(pool_size=(2, 2)),
        layers.Flatten(),
        layers.Dropout(0.5),
        layers.Dense(num_classes, activation="softmax"),
    ]
)

model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 13, 13, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 11, 11, 64)        18496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 5, 5, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 1600)              0
_________________________________________________________________
dropout (Dropout)            (None, 1600)              0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                16010
=================================================================
Total params: 34,826
Trainable params: 34,826
Non-trainable params: 0
_________________________________________________________________
```

In [11]:

```
#Train Model
batch_size = 128
epochs = 15

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

model.fit(x_train, y_train, batch_size=batch_size, epochs=epochs, validation_split=0.1)
```

```
Epoch 1/15
422/422 [==============================] - 47s 108ms/step - loss: 0.3708 - accuracy: 0.8879 - val_loss: 0.0784 - val_accura
cy: 0.9795
Epoch 2/15
422/422 [==============================] - 51s 121ms/step - loss: 0.1084 - accuracy: 0.9675 - val_loss: 0.0563 - val_accura
cy: 0.9842
Epoch 3/15
422/422 [==============================] - 47s 112ms/step - loss: 0.0816 - accuracy: 0.9748 - val_loss: 0.0443 - val_accura
cy: 0.9890
Epoch 4/15
422/422 [==============================] - 55s 130ms/step - loss: 0.0697 - accuracy: 0.9782 - val_loss: 0.0409 - val_accura
cy: 0.9890
Epoch 5/15
422/422 [==============================] - 50s 118ms/step - loss: 0.0617 - accuracy: 0.9809 - val_loss: 0.0413 - val_accura
cy: 0.9898
Epoch 6/15
422/422 [==============================] - 46s 110ms/step - loss: 0.0546 - accuracy: 0.9829 - val_loss: 0.0379 - val_accura
cy: 0.9888
Epoch 7/15
422/422 [==============================] - 45s 106ms/step - loss: 0.0516 - accuracy: 0.9840 - val_loss: 0.0371 - val_accura
cy: 0.9897
Epoch 8/15
422/422 [==============================] - 43s 101ms/step - loss: 0.0484 - accuracy: 0.9850 - val_loss: 0.0321 - val_accura
cy: 0.9917
Epoch 9/15
422/422 [==============================] - 44s 103ms/step - loss: 0.0436 - accuracy: 0.9866 - val_loss: 0.0336 - val_accura
cy: 0.9920
Epoch 10/15
422/422 [==============================] - 44s 103ms/step - loss: 0.0422 - accuracy: 0.9864 - val_loss: 0.0336 - val_accura
cy: 0.9907
Epoch 11/15
422/422 [==============================] - 43s 103ms/step - loss: 0.0412 - accuracy: 0.9865 - val_loss: 0.0318 - val_accura
cy: 0.9922
Epoch 12/15
422/422 [==============================] - 43s 103ms/step - loss: 0.0386 - accuracy: 0.9877 - val_loss: 0.0300 - val_accura
cy: 0.9923
Epoch 13/15
422/422 [==============================] - 44s 103ms/step - loss: 0.0349 - accuracy: 0.9884 - val_loss: 0.0293 - val_accura
cy: 0.9918
Epoch 14/15
422/422 [==============================] - 46s 110ms/step - loss: 0.0340 - accuracy: 0.9892 - val_loss: 0.0274 - val_accura
cy: 0.9928
Epoch 15/15
422/422 [==============================] - 50s 118ms/step - loss: 0.0333 - accuracy: 0.9892 - val_loss: 0.0302 - val_accura
cy: 0.9913
```

Out[11]: `<keras.callbacks.History at 0x2258eda9040>`

In [12]:

```
#Test model -Evaluate
score = model.evaluate(x_test, y_test, verbose=0)
print("Test loss:", score[0])
print("Test accuracy:", score[1])
```

```
Test loss: 0.025686144828796387
Test accuracy: 0.9912999868392944
```

In [13]:

```
model.save('C:\\Users\\Admin\\Downloads\\CNN')
```

```
INFO:tensorflow:Assets written to: C:\Users\Admin\Downloads\CNN\assets
```

Testing models through GUI Application

In [17]:

```
#GUI
from keras.models import load_model
from tkinter import *
import tkinter as tk
import win32gui
from PIL import ImageGrab, Image
import numpy as np
model = load_model('C:\\Users\\Admin\\Downloads\\CNN')
def predict_digit(img):
    #resize image to 28x28 pixels
    img = img.resize((28,28))
    #convert rgb to grayscale
    img = img.convert('L')
    img = np.array(img)
    #reshaping to support our model input and normalizing
    img = img.reshape(1,28,28,1)
    img = img/255.0
    #predicting the class
    res = model.predict([img])[0]
    return np.argmax(res), max(res)
class App(tk.Tk):
    def __init__(self):
        tk.Tk.__init__(self)
        self.x = self.y = 0
        # Creating elements
        self.canvas = tk.Canvas(self, width=300, height=300, bg = "white", cursor="cross")
        self.label = tk.Label(self, text="Thinking..", font=("Helvetica", 48))
        self.classify_btn = tk.Button(self, text = "Recognise", command =         self.classify_handwriting)
        self.button_clear = tk.Button(self, text = "Clear", command = self.clear_all)
        # Grid structure
        self.canvas.grid(row=0, column=0, pady=2, sticky=W, )
        self.label.grid(row=0, column=1,pady=2, padx=2)
        self.classify_btn.grid(row=1, column=1, pady=2, padx=2)
        self.button_clear.grid(row=1, column=0, pady=2)
        #self.canvas.bind("<Motion>", self.start_pos)
        self.canvas.bind("<B1-Motion>", self.draw_lines)
    def clear_all(self):
        self.canvas.delete("all")
    def classify_handwriting(self):
        HWND = self.canvas.winfo_id() # get the handle of the canvas
        rect = win32gui.GetWindowRect(HWND) # get the coordinate of the canvas
        im = ImageGrab.grab(rect)
        digit, acc = predict_digit(im)
        self.label.configure(text= str(digit)+', '+ str(int(acc*100))+'%')
    def draw_lines(self, event):
        self.x = event.x
        self.y = event.y
        r=8
        self.canvas.create_oval(self.x-r, self.y-r, self.x + r, self.y + r, fill='black')
app = App()
mainloop()
```

Testing models through GUI Application

In [17]:

```
#GUI
from keras.models import load_model
from tkinter import *
import tkinter as tk
import win32gui
from PIL import ImageGrab, Image
import numpy as np
model = load_model('C:\\Users\\Admin\\Downloads\\FCNN')
def predict_digit(img):
    #resize image to 28x28 pixels
    img = img.resize((28,28))
    #convert rgb to grayscale
    img = img.convert('L')
    img = np.array(img)
    #reshaping to support our model input and normalizing
    img = img.reshape(1,28,28,1)
    img = img/255.0
    #predicting the class
    res = model.predict([img])[0]
    return np.argmax(res), max(res)
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    def draw_lines(self, event):
        self.x = event.x
        self.y = event.y
        r=8
        self.canvas.create_oval(self.x-r, self.y-r, self.x + r, self.y + r, fill='black')
app = App()
mainloop()
```
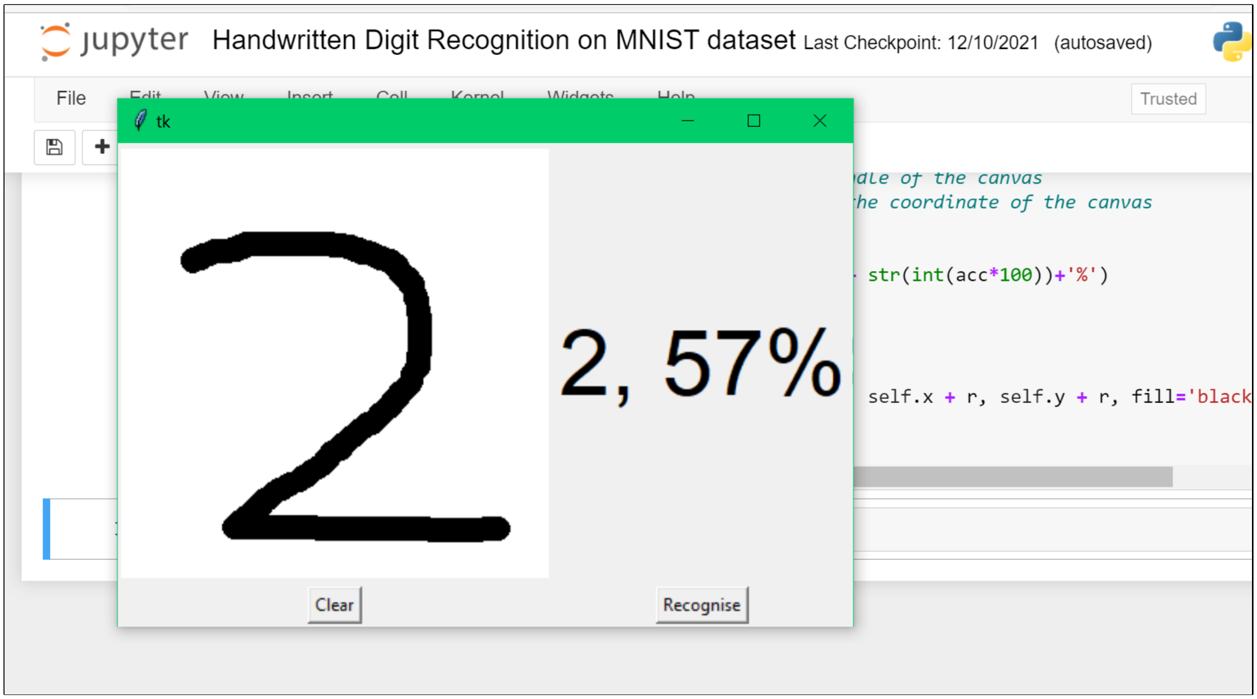

GUI TESTING

Fully Convolutional Network



Convolutional Neural Network