PART I: Build, Train, and Test CNN on MNIST Dataset

Project Report – CNN on MNIST with TensorFlow.

In [1]:
```
import numpy as np
import pandas as pd
```

In [2]:
```
import matplotlib.pyplot as plt
%matplotlib inline
```

In [3]:
```
import tensorflow as tf
from tensorflow.examples.tutorials.mnist import input_data
```

In [4]:
```
mnist=input_data.read_data_sets("MNIST_data/", one_hot=True)
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/3864835019.py:1: read_data_sets (from ten
sorflow.contrib.learn.python.learn.datasets.mnist) is deprecated and will be removed
in a future version.
Instructions for updating:
Please use alternatives such as official/mnist/dataset.py from tensorflow/models.
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/contri
b/learn/python/learn/datasets/mnist.py:260: maybe_download (from tensorflow.contrib.l
earn.python.learn.datasets.base) is deprecated and will be removed in a future versio
n.
Instructions for updating:
Please write your own downloading logic.
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/contri
b/learn/python/learn/datasets/mnist.py:262: extract_images (from tensorflow.contrib.l
earn.python.learn.datasets.mnist) is deprecated and will be removed in a future versi
on.
Instructions for updating:
Please use tf.data to implement this functionality.
Extracting MNIST_data/train-images-idx3-ubyte.gz
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/contri
b/learn/python/learn/datasets/mnist.py:267: extract_labels (from tensorflow.contrib.l
earn.python.learn.datasets.mnist) is deprecated and will be removed in a future versi
on.
Instructions for updating:
Please use tf.data to implement this functionality.
Extracting MNIST_data/train-labels-idx1-ubyte.gz
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/contri
b/learn/python/learn/datasets/mnist.py:110: dense_to_one_hot (from tensorflow.contri
b.learn.python.learn.datasets.mnist) is deprecated and will be removed in a future ve
rsion.
Instructions for updating:
Please use tf.one_hot on tensors.
Extracting MNIST_data/t10k-images-idx3-ubyte.gz
Extracting MNIST_data/t10k-labels-idx1-ubyte.gz
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow_core/contri
b/learn/python/learn/datasets/mnist.py:290: DataSet.__init__ (from tensorflow.contri
b.learn.python.learn.datasets.mnist) is deprecated and will be removed in a future ve
rsion.
Instructions for updating:
Please use alternatives such as official/mnist/dataset.py from tensorflow/models.
```

In [5]:
```
type(mnist)
```

Out[5]:
```
tensorflow.contrib.learn.python.learn.datasets.base.Datasets
```

In [6]:
```
mnist.train.num_examples
```

Out[6]:
```
55000
```

In [7]:
```
mnist.test.num_examples
```

Out[7]:
```
10000
```

Initialize Bias

In [8]:
```
def initialize_weights (filter_shape):
```

```
    init_random_dist=tf.truncated_normal(filter_shape, stddev=0.1)

    return(tf.Variable(init_random_dist))
```

In [9]:
```
def initialize_bias(bias_shape):

    initial_bias_value=tf.constant(0.1, shape=bias_shape)

    return(tf.Variable(initial_bias_value))
```

Initialize Weights In Filter

In [10]:
```
def create_convolution_layer_and_compute_dot_product(inputs, filter_shape):

    filter_initialized_with_weights=initialize_weights(filter_shape)

    conv_layer_outputs=tf.nn.conv2d(inputs,
                                    filter_initialized_with_weights,
                                    strides=[1,1,1,1],
                                   padding="SAME")
    return(conv_layer_outputs)
```

In [11]:
```
def create_relu_layer_and_compute_dotproduct_plus_b(inputs, filter_shape):
    b=initialize_bias([filter_shape[3]])
    relu_layer_outputs=tf.nn.relu(inputs+b)
    return(relu_layer_outputs)
```

In [12]:
```
def create_maxpool2by2_and_reduce_spatial_size(inputs):
    pooling_layer_outputs=tf.nn.max_pool(inputs, ksize=[1,2,2,1], strides=[1,2,2,1], p
    return pooling_layer_outputs
```

In [13]:
```
def create_fully_connected_layer_and_compute_dotproduct_plus_bias(inputs, output_size)
    input_size=int(inputs.get_shape()[1])
    w=initialize_weights([input_size, output_size])
    b=initialize_bias([output_size])
    fc_xW_plus_bias_outputs=tf.matmul(inputs, w)+b
    return(fc_xW_plus_bias_outputs)
```

Create Place holders for inputs and Labels: x and y_true

In [14]:
```
x=tf.compat.v1.placeholder(tf.float32, shape=[None, 784])
```

In [15]:
```
y_true=tf.compat.v1.placeholder(tf.float32, [None, 10])
```

In [16]:
```
x_image=tf.reshape(x, [-1,28,28,1])
```

In [17]:
```
conv_layer1_outputs \
    =create_convolution_layer_and_compute_dot_product(x_image, filter_shape=[5,5,1,32]
conv_relu_layer1_outputs \
    =create_relu_layer_and_compute_dotproduct_plus_b(conv_layer1_outputs, filter_shape
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/3226569172.py:3: The name tf.truncated_no
rmal is deprecated. Please use tf.random.truncated_normal instead.
```

Create 1st pooling layer and reduce spatial size

In [18]:
```
# create the 1st pooling layyes
# then reduce the spatial size if the input data
# retrun outputs of the layer

pooling_layer_1_outputs=create_maxpool2by2_and_reduce_spatial_size(conv_relu_layer1_ou
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/3577672229.py:2: The name tf.nn.max_pool
is deprecated. Please use tf.nn.max_pool2d instead.
```

Make it ready to be into 1 st full connected layer

In [19]:
```
# reshape and platten the output of the plling layer
# prepare to feed the output data into the frist fully connected layer

pooling_layer_1_outputs_flat=tf.reshape(pooling_layer_1_outputs, [-1,14*14*32])
```

In [20]:
```
conv_layer_2_outputs \
    =create_convolution_layer_and_compute_dot_product(pooling_layer_1_outputs, filter_
conv_relu_layer_2_outputs \
    =create_relu_layer_and_compute_dotproduct_plus_b(conv_layer_2_outputs, filter_shap
```

In [21]:
```
pooling_layer_2_outputs=create_maxpool2by2_and_reduce_spatial_size(conv_relu_layer_2_c
```

In [22]:
```
pooling_layer_2_outputs_flat=tf.reshape(pooling_layer_2_outputs, [-1,7*7*64])
```

In [23]:
```
fc_layer1_outputs=create_fully_connected_layer_and_compute_dotproduct_plus_bias(poolir

fc_relu_layer1_outputs=tf.nn.relu(fc_layer1_outputs)
```

In [24]:
```
hold_prob=tf.placeholder(tf.float32)

fc_dropout_outputs=tf.nn.dropout(fc_relu_layer1_outputs, keep_prob=hold_prob)
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/1489154089.py:1: The name tf.placeholder
is deprecated. Please use tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /tmp/ipykernel_3744/1489154089.py:3: calling dropout (from te
nsorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a fut
ure version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob
`.
```

In [25]:
```
y_pred=create_fully_connected_layer_and_compute_dotproduct_plus_bias(fc_dropout_output
```

In [26]:
```
softmax_cross_entropy_loss=tf.nn.softmax_cross_entropy_with_logits(labels=y_true, logi
cross_entropy_mean=tf.reduce_mean(softmax_cross_entropy_loss)
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/3474321909.py:1: softmax_cross_entropy_wi
th_logits (from tensorflow.python.ops.nn_ops) is deprecated and will be removed in a
future version.
Instructions for updating:

Future major versions of TensorFlow will allow gradients to flow
into the labels input on backprop by default.

See `tf.nn.softmax_cross_entropy_with_logits_v2`.
```

In [27]:
```
optimizer=tf.train.AdamOptimizer(learning_rate=0.001)
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/184395198.py:1: The name tf.train.AdamOpt
imizer is deprecated. Please use tf.compat.v1.train.AdamOptimizer instead.
```

In [28]:
```
cnn_trainer=optimizer.minimize(cross_entropy_mean)
```

In [29]:
```
vars_initializer=tf.global_variables_initializer()
steps=5000
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/2865824514.py:1: The name tf.global_varia
bles_initializer is deprecated. Please use tf.compat.v1.global_variables_initializer
instead.
```

In [30]:
```
with tf.Session() as sess:

    sess.run(vars_initializer)
    for i in range(steps):
        batch_x, batch_y=mnist.train.next_batch(50)
        sess.run(cnn_trainer, feed_dict={x: batch_x, y_true: batch_y, hold_prob: 0.5})
        if i % 100 == 0:
            print("On step: {}".format(i))
            print("Accuracy: ")

            matches=tf.equal(tf.argmax(y_pred, 1), tf.argmax(y_true, 1))
            acc=tf.reduce_mean(tf.cast(matches, tf.float32))
            test_accuracy=sess.run(acc, feed_dict={x: mnist.test.images,
                                                   y_true: mnist.test.labels,
                                                   hold_prob: 1.0})
            print(test_accuracy)
            print('\n')
```

```
WARNING:tensorflow:From /tmp/ipykernel_3744/1131664400.py:1: The name tf.Session is d
eprecated. Please use tf.compat.v1.Session instead.
```

```
User settings:

   KMP_AFFINITY=granularity=fine,verbose,compact,1,0
   KMP_BLOCKTIME=0
   KMP_DUPLICATE_LIB_OK=True
   KMP_INIT_AT_FORK=FALSE
   KMP_SETTINGS=1
   OMP_NUM_THREADS=8

Effective settings:

   KMP_ABORT_DELAY=0
   KMP_ADAPTIVE_LOCK_PROPS='1,1024'
   KMP_ALIGN_ALLOC=64
   KMP_ALL_THREADPRIVATE=128
   KMP_ATOMIC_MODE=2
   KMP_BLOCKTIME=0
   KMP_CPUINFO_FILE: value is not defined
   KMP_DETERMINISTIC_REDUCTION=false
   KMP_DEVICE_THREAD_LIMIT=2147483647
   KMP_DISP_HAND_THREAD=false
   KMP_DISP_NUM_BUFFERS=7
   KMP_DUPLICATE_LIB_OK=true
   KMP_FORCE_REDUCTION: value is not defined
   KMP_FOREIGN_THREADS_THREADPRIVATE=true
   KMP_FORKJOIN_BARRIER='2,2'
   KMP_FORKJOIN_BARRIER_PATTERN='hyper,hyper'
   KMP_FORKJOIN_FRAMES=true
   KMP_FORKJOIN_FRAMES_MODE=3
   KMP_GTID_MODE=3
   KMP_HANDLE_SIGNALS=false
   KMP_HOT_TEAMS_MAX_LEVEL=1
   KMP_HOT_TEAMS_MODE=0
   KMP_INIT_AT_FORK=true
   KMP_ITT_PREPARE_DELAY=0
   KMP_LIBRARY=throughput
   KMP_LOCK_KIND=queuing
   KMP_MALLOC_POOL_INCR=1M
   KMP_MWAIT_HINTS=0
   KMP_NUM_LOCKS_IN_BLOCK=1
   KMP_PLAIN_BARRIER='2,2'
   KMP_PLAIN_BARRIER_PATTERN='hyper,hyper'
   KMP_REDUCTION_BARRIER='1,1'
   KMP_REDUCTION_BARRIER_PATTERN='hyper,hyper'
   KMP_SCHEDULE='static,balanced;guided,iterative'
   KMP_SETTINGS=true
   KMP_SPIN_BACKOFF_PARAMS='4096,100'
   KMP_STACKOFFSET=64
   KMP_STACKPAD=0
   KMP_STACKSIZE=8M
   KMP_STORAGE_MAP=false
   KMP_TASKING=2
   KMP_TASKLOOP_MIN_TASKS=0
   KMP_TASK_STEALING_CONSTRAINT=1
   KMP_TEAMS_THREAD_LIMIT=8
   KMP_TOPOLOGY_METHOD=all
   KMP_USER_LEVEL_MWAIT=false
   KMP_USE_YIELD=1
   KMP_VERSION=false
   KMP_WARNINGS=true
```

```
   OMP_AFFINITY_FORMAT='OMP: pid %P tid %i thread %n bound to OS proc set {%A}'
   OMP_ALLOCATOR=omp_default_mem_alloc
   OMP_CANCELLATION=false
   OMP_DEBUG=disabled
   OMP_DEFAULT_DEVICE=0
   OMP_DISPLAY_AFFINITY=false
   OMP_DISPLAY_ENV=false
   OMP_DYNAMIC=false
   OMP_MAX_ACTIVE_LEVELS=2147483647
   OMP_MAX_TASK_PRIORITY=0
   OMP_NESTED=false
   OMP_NUM_THREADS='8'
   OMP_PLACES: value is not defined
   OMP_PROC_BIND='intel'
   OMP_SCHEDULE='static'
   OMP_STACKSIZE=8M
   OMP_TARGET_OFFLOAD=DEFAULT
   OMP_THREAD_LIMIT=2147483647
   OMP_TOOL=enabled
   OMP_TOOL_LIBRARIES: value is not defined
   OMP_WAIT_POLICY=PASSIVE
   KMP_AFFINITY='verbose,warnings,respect,granularity=fine,compact,1,0'

2024-02-23 01:41:25.076936: I tensorflow/core/platform/profile_utils/cpu_utils.cc:94]
CPU Frequency: 2200210000 Hz
2024-02-23 01:41:25.077705: I tensorflow/compiler/xla/service/service.cc:168] XLA ser
vice 0x559d7b20bf50 initialized for platform Host (this does not guarantee that XLA w
ill be used). Devices:
2024-02-23 01:41:25.077754: I tensorflow/compiler/xla/service/service.cc:176]   Strea
mExecutor device (0): Host, Default Version
2024-02-23 01:41:25.079231: I tensorflow/core/common_runtime/process_util.cc:136] Cre
ating new thread pool with default inter op setting: 2. Tune using inter_op_paralleli
sm_threads for best performance.
OMP: Info #212: KMP_AFFINITY: decoding x2APIC ids.
OMP: Info #210: KMP_AFFINITY: Affinity capable, using global cpuid leaf 11 info
OMP: Info #154: KMP_AFFINITY: Initial OS proc set respected: 0-7
OMP: Info #156: KMP_AFFINITY: 8 available OS procs
OMP: Info #157: KMP_AFFINITY: Uniform topology
OMP: Info #179: KMP_AFFINITY: 1 packages x 4 cores/pkg x 2 threads/core (4 total core
s)
OMP: Info #214: KMP_AFFINITY: OS proc to physical thread map:
OMP: Info #171: KMP_AFFINITY: OS proc 0 maps to package 0 core 0 thread 0
OMP: Info #171: KMP_AFFINITY: OS proc 4 maps to package 0 core 0 thread 1
OMP: Info #171: KMP_AFFINITY: OS proc 1 maps to package 0 core 1 thread 0
OMP: Info #171: KMP_AFFINITY: OS proc 5 maps to package 0 core 1 thread 1
OMP: Info #171: KMP_AFFINITY: OS proc 2 maps to package 0 core 2 thread 0
OMP: Info #171: KMP_AFFINITY: OS proc 6 maps to package 0 core 2 thread 1
OMP: Info #171: KMP_AFFINITY: OS proc 3 maps to package 0 core 3 thread 0
OMP: Info #171: KMP_AFFINITY: OS proc 7 maps to package 0 core 3 thread 1
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5189 thread 0 bound to OS proc set 0
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5189 thread 1 bound to OS proc set 1
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5191 thread 2 bound to OS proc set 2
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5192 thread 3 bound to OS proc set 3
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5195 thread 6 bound to OS proc set 6
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5194 thread 5 bound to OS proc set 5
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5196 thread 7 bound to OS proc set 7
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5193 thread 4 bound to OS proc set 4
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5197 thread 8 bound to OS proc set 0
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5188 thread 9 bound to OS proc set 1
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5200 thread 12 bound to OS proc set 4
```

```
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5199 thread 11 bound to OS proc set 3
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5198 thread 10 bound to OS proc set 2
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5203 thread 15 bound to OS proc set 7
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5201 thread 13 bound to OS proc set 5
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5204 thread 16 bound to OS proc set 0
OMP: Info #250: KMP_AFFINITY: pid 3744 tid 5202 thread 14 bound to OS proc set 6
```

```
On step: 0
Accuracy:
0.1968


On step: 100
Accuracy:
0.9449


On step: 200
Accuracy:
0.9583


On step: 300
Accuracy:
0.9686


On step: 400
Accuracy:
0.9758


On step: 500
Accuracy:
0.9785


On step: 600
Accuracy:
0.9786


On step: 700
Accuracy:
0.9808


On step: 800
Accuracy:
0.9817


On step: 900
Accuracy:
0.982


On step: 1000
Accuracy:
0.9828


On step: 1100
Accuracy:
0.9866
```

```
On step: 1200
Accuracy:
0.9856


On step: 1300
Accuracy:
0.9847


On step: 1400
Accuracy:
0.9864


On step: 1500
Accuracy:
0.9875


On step: 1600
Accuracy:
0.9849


On step: 1700
Accuracy:
0.9864


On step: 1800
Accuracy:
0.9884


On step: 1900
Accuracy:
0.9878


On step: 2000
Accuracy:
0.9855


On step: 2100
Accuracy:
0.9884


On step: 2200
Accuracy:
0.9886


On step: 2300
Accuracy:
0.9889
```

```
On step: 2400
Accuracy:
0.9867


On step: 2500
Accuracy:
0.9889


On step: 2600
Accuracy:
0.9897


On step: 2700
Accuracy:
0.987


On step: 2800
Accuracy:
0.9857


On step: 2900
Accuracy:
0.9884


On step: 3000
Accuracy:
0.9878


On step: 3100
Accuracy:
0.9898


On step: 3200
Accuracy:
0.9893


On step: 3300
Accuracy:
0.9881


On step: 3400
Accuracy:
0.988


On step: 3500
Accuracy:
0.9892
```

```
On step: 3600
Accuracy:
0.9874


On step: 3700
Accuracy:
0.9892


On step: 3800
Accuracy:
0.9889


On step: 3900
Accuracy:
0.9891


On step: 4000
Accuracy:
0.99


On step: 4100
Accuracy:
0.9901


On step: 4200
Accuracy:
0.9906


On step: 4300
Accuracy:
0.9896


On step: 4400
Accuracy:
0.9911


On step: 4500
Accuracy:
0.9898


On step: 4600
Accuracy:
0.9906


On step: 4700
Accuracy:
0.9891
```

```
On step: 4800
Accuracy:
0.9884


On step: 4900
Accuracy:
0.9904
```

In [ ]: