Lab1

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Quick Note * For Part I, Part II, the code is in Lab1.ipynb. * For Part III, the code is in Part III folder. * Part IV, Part V: https://colab.research.google.com/drive/1MCXCnRyy2TOcZwABKQ83Vm_tzYVHrpIi

4 PART I: Raspberry Pi Setup and Basics

Part I - 6 pts * (1 pt) Show outputs from cat /proc/cpuinfo (0.5 pt) and ifconfig (0.5 pt) of the computer on which you have been working on this lab. * (5 pts) Include screen snapshots to show that your news display code is working correctly on your system: * Send POST request (1 pt) * Get respond from server (1 pt) * Retrieve string from server response (2 pts)

Raspberry Pi Setup

I connected to the host in ZJU Internation Campus, and here is the result (there are 32 processors):

[1]:
```
from IPython.display import Image
Image(filename = "Images/processor1.png")
```

[1]:

```
[3170112253@localhost ~]$ cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 63
model name      : Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
stepping        : 2
microcode       : 67
cpu MHz         : 2600.265
cache size      : 20480 KB
physical id     : 0
siblings        : 16
core id         : 0
cpu cores       : 8
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 15
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm c
onstant_tsc arch_perfmon pebs bts rep_good xtopology nonstop_tsc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 fma cx16 xtpr pdcm pcid d
ca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm ida arat epb xsaveopt pln pts dtherm invpcid_single ssbd pti retpoline ibr
s ibpb tpr_shadow vnmi flexpriority ept vpid fsgsbase bmi1 avx2 smep bmi2 erms invpcid cqm cqm_llc cqm_occup_llc md_clear flush_l1d
bogomips        : 5200.53
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:

processor       : 1
vendor_id       : GenuineIntel
cpu family      : 6
model           : 63
model name      : Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
stepping        : 2
microcode       : 67
cpu MHz         : 2600.265
cache size      : 20480 KB
physical id     : 1
siblings        : 16
core id         : 0
cpu cores       : 8
apicid          : 16
initial apicid  : 16
fpu             : yes
fpu_exception   : yes
cpuid level     : 15
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm c
onstant_tsc arch_perfmon pebs bts rep_good xtopology nonstop_tsc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 fma cx16 xtpr pdcm pcid d
ca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm ida arat epb xsaveopt pln pts dtherm invpcid_single ssbd pti retpoline ibr
s ibpb tpr_shadow vnmi flexpriority ept vpid fsgsbase bmi1 avx2 smep bmi2 erms invpcid cqm cqm_llc cqm_occup_llc md_clear flush_l1d
bogomips        : 5199.25
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:
```

[2]:
```python
Image(filename = "Images/processor2.png")
```

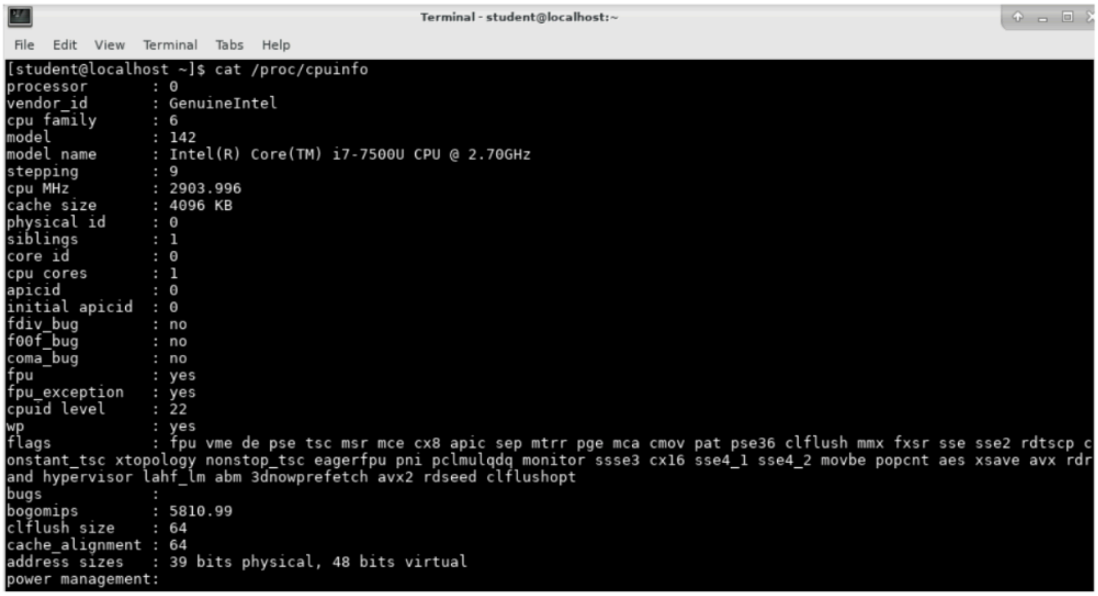
[2]:

```
processor       : 30
vendor_id       : GenuineIntel
cpu family      : 6
model           : 63
model name      : Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
stepping        : 2
microcode       : 67
cpu MHz         : 2600.265
cache size      : 20480 KB
physical id     : 0
siblings        : 16
core id         : 7
cpu cores       : 8
apicid          : 15
initial apicid  : 15
fpu             : yes
fpu_exception   : yes
cpuid level     : 15
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm c
onstant_tsc arch_perfmon pebs bts rep_good xtopology nonstop_tsc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 fma cx16 xtpr pdcm pcid d
ca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm ida arat epb xsaveopt pln pts dtherm invpcid_single ssbd pti retpoline ibr
s ibpb tpr_shadow vnmi flexpriority ept vpid fsgsbase bmi1 avx2 smep bmi2 erms invpcid cqm cqm_llc cqm_occup_llc md_clear flush_l1d
bogomips        : 5200.53
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:

processor       : 31
vendor_id       : GenuineIntel
cpu family      : 6
model           : 63
model name      : Intel(R) Xeon(R) CPU E5-2640 v3 @ 2.60GHz
stepping        : 2
microcode       : 67
cpu MHz         : 2600.265
cache size      : 20480 KB
physical id     : 1
siblings        : 16
core id         : 7
cpu cores       : 8
apicid          : 31
initial apicid  : 31
fpu             : yes
fpu_exception   : yes
cpuid level     : 15
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm c
onstant_tsc arch_perfmon pebs bts rep_good xtopology nonstop_tsc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 fma cx16 xtpr pdcm pcid d
ca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm ida arat epb xsaveopt pln pts dtherm invpcid_single ssbd pti retpoline ibr
s ibpb tpr_shadow vnmi flexpriority ept vpid fsgsbase bmi1 avx2 smep bmi2 erms invpcid cqm cqm_llc cqm_occup_llc md_clear flush_l1d
bogomips        : 5199.25
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:
```

This is the result from my Dell laptop:

[3]:
```
Image(filename = "Images/processor3.png")
```

[3]:



This is the result of my network interface configuration:

[4]:
```
Image(filename = "Images/ifconfig.png")
```

[4]:

```
yuchengjin — 3170112253@localhost:~ — ssh 3170112253@10.105.100.202 — 136×64
[3170112253@localhost ~]$ ifconfig
em1       Link encap:Ethernet  HWaddr 18:66:DA:E6:79:7C
          inet addr:10.105.100.202  Bcast:10.105.100.255  Mask:255.255.255.0
          inet6 addr: fe80::1a66:daff:fee6:797c/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:18613516 errors:0 dropped:0 overruns:0 frame:0
          TX packets:171137 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:3932427110 (3.6 GiB)  TX bytes:42586959 (40.6 MiB)
          Interrupt:41

em2       Link encap:Ethernet  HWaddr 18:66:DA:E6:79:7D
          inet6 addr: fe80::1a66:daff:fee6:797d/64 Scope:Link
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:3297 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:578268 (564.7 KiB)  TX bytes:270 (270.0 b)
          Interrupt:45

em3       Link encap:Ethernet  HWaddr 18:66:DA:E6:79:7E
          inet6 addr: fe80::1a66:daff:fee6:797e/64 Scope:Link
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:553 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:106970 (104.4 KiB)  TX bytes:270 (270.0 b)
          Interrupt:40

em4       Link encap:Ethernet  HWaddr 18:66:DA:E6:79:7F
          inet6 addr: fe80::1a66:daff:fee6:797f/64 Scope:Link
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:9721 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1686195 (1.6 MiB)  TX bytes:270 (270.0 b)
          Interrupt:44

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:82 errors:0 dropped:0 overruns:0 frame:0
          TX packets:82 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:5586 (5.4 KiB)  TX bytes:5586 (5.4 KiB)

p5p1      Link encap:Ethernet  HWaddr F4:E9:D4:9E:26:50
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
          Interrupt:42 Memory:93000000-937fffff

p5p2      Link encap:Ethernet  HWaddr F4:E9:D4:9E:26:52
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
          Interrupt:45 Memory:92000000-927fffff
```

NumPy and TensorFlow Setup

[5]:
```python
import numpy as np
np.__version__
```

[5]: '1.16.4'

[6]:
```python
import warnings
warnings.filterwarnings("ignore")
import tensorflow.compat.v1 as tf
```

```
# make tf 2.0.0 version compatible with 1.14 grammar
tf.disable_v2_behavior()
tf.__version__
```

```
WARNING:tensorflow:From /Users/yuchengjin/anaconda3/lib/python3.7/site-
packages/tensorflow_core/python/compat/v2_compat.py:65:
disable_resource_variables (from tensorflow.python.ops.variable_scope) is
deprecated and will be removed in a future version.
Instructions for updating:
non-resource variables are not supported in the long term
```

[6]: '2.0.0'

HTTP Request in Python

Please write a Python script for your Raspberry Pi to implement this feature: * In your Raspberry Pi, use Python to send a POST request to this webpage: https://courses.engr.illinois.edu/ece498icc/sp2020/lab1_string.php * Your POST request should contain two data fields netid and name. Fill your NetID and name in these two fields respectively. The server will record your NetID and your name. * The customized news is hidden in the response from the server. The news is a string of length 400. The ith character in the string is the (i*498)th character in the server's response. The index starts from 0. Please retrieve the customized news from the server's response. You are NOT allowed to use explicit for loops, please use Python generator expressions instead.* Report the customized news you get from the server.

[7]:
```
import urllib.parse
import urllib.request

# send POST request
url = 'https://courses.engr.illinois.edu/ece498icc/sp2020/lab1_string.php'
values = {'netid':'yucheng9', 'name':'Yucheng Jin'}

data = urllib.parse.urlencode(values)
data = data.encode('ascii')

# get respond from server
req = urllib.request.Request(url, data)
with urllib.request.urlopen(req) as response:

# retrieve & decode the string
    the_page = response.read()

decoded_news = the_page.decode('ascii')
news = [decoded_news[i] for i in range(0, 400*498, 498)]
```

[8]:
```
print("".join(news))
```

```
The police stops a computer hardware engineer: Your light isn't working. You
have to get off your bike." IT guy: "I tried that but the light still isn't
working.  Hello Yucheng Jin! I hope you enjoy the course.
```

5 PART II: NumPy Basics

Part II - 6 pts * (6 pts) You need to print out the array A, B, C, D, E, F, and the result in Step 8. * Correct A, E, and result from Step 8 (1 pt x 3) * Correct B, C, D, F. (0.5 pt x 4) * Attach the screen shots for each step and write down the approaches you used.

Include your source code. Without this source code you will not receive any points for Part II!

NumPy array generation

Step 1: Generate a 2-dim all-zero array A, with the size of 9 x 6 (row x column).

[9]:
```
# use np.zeros((9,6)) to generate a 2d array of size 9 * 6
A = np.zeros((9,6))
A
```

[9]:
```
array([[0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.],
       [0., 0., 0., 0., 0., 0.]])
```

Step 2: Create a block-I shape by replacing certain elements from 0 to 1 in array A.

[10]:
```
# use slicing to create the I-shape block
A[0,1:5] = 1
A[1,1:5] = 1
A[2,2:4] = 1
A[3,2:4] = 1
A[4,2:4] = 1
A[5,2:4] = 1
A[6,2:4] = 1
A[7,1:5] = 1
A[8,1:5] = 1
A
```

[10]:
```
array([[0., 1., 1., 1., 1., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 1., 1., 1., 1., 0.]])
```

Step 3: Generate a 2-dim array B by filling zero-vector at the top and bottom of the array A.

[11]:
```
# X is a vector of six 0s
X = np.zeros((1,6))
# B is a copy of A
```

```
B = A.copy()
# concatenate X to the top & bottom of B
B = np.concatenate((X,B), axis=0)
B = np.concatenate((B,X), axis=0)
B
```

[11]:
```
array([[0., 0., 0., 0., 0., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 0., 1., 1., 0., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 1., 1., 1., 1., 0.],
       [0., 0., 0., 0., 0., 0.]])
```

Numerical computation

Step 4: Generate a 2-dim array C, with numbers 1, 2, 3, ..., 65, 66 filled in row by row, starting from the top-left corner of the array. The size of C is 11 x 6 (row x column, the same size as array B).

[12]:
```
# use np.arange(1,67) to generate a 1d array with 1, 2, 3, ..., 66
C = np.arange(1,67)
# use reshape((11,6)) to convert C into a 2d array of size 11 * 6
C = C.reshape((11,6))
C
```

[12]:
```
array([[ 1,  2,  3,  4,  5,  6],
       [ 7,  8,  9, 10, 11, 12],
       [13, 14, 15, 16, 17, 18],
       [19, 20, 21, 22, 23, 24],
       [25, 26, 27, 28, 29, 30],
       [31, 32, 33, 34, 35, 36],
       [37, 38, 39, 40, 41, 42],
       [43, 44, 45, 46, 47, 48],
       [49, 50, 51, 52, 53, 54],
       [55, 56, 57, 58, 59, 60],
       [61, 62, 63, 64, 65, 66]])
```

Step 5: Perform element-wise multiplication between B and C and store the result in array D.

[13]:
```
# use np.multiply(B,C) to realize element-wise multiplication
D = np.multiply(B,C)
D
```

[13]:
```
array([[ 0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  8.,  9., 10., 11.,  0.],
       [ 0., 14., 15., 16., 17.,  0.],
       [ 0.,  0., 21., 22.,  0.,  0.],
```

```
[ 0.,  0., 27., 28.,  0.,  0.],
[ 0.,  0., 33., 34.,  0.,  0.],
[ 0.,  0., 39., 40.,  0.,  0.],
[ 0.,  0., 45., 46.,  0.,  0.],
[ 0., 50., 51., 52., 53.,  0.],
[ 0., 56., 57., 58., 59.,  0.],
[ 0.,  0.,  0.,  0.,  0.,  0.]])
```

Step 6: Grab the non-zero elements in D and store into a new 1-D array E.

[14]:
```
# first flatten the array then grab all non-zero elements
E = D.ravel()
E = E[E != 0]
E
```

[14]:
```
array([ 8.,  9., 10., 11., 14., 15., 16., 17., 21., 22., 27., 28., 33.,
       34., 39., 40., 45., 46., 50., 51., 52., 53., 56., 57., 58., 59.])
```

Step 7: Normalize the elements in E and store in F using equations:

[15]:
```
# normalize the elements in E and store the results in F
maxv, minv = E.max(), E.min()
F = (E - minv) / (maxv - minv)
F
```

[15]:
```
array([0.        , 0.01960784, 0.03921569, 0.05882353, 0.11764706,
       0.1372549 , 0.15686275, 0.17647059, 0.25490196, 0.2745098 ,
       0.37254902, 0.39215686, 0.49019608, 0.50980392, 0.60784314,
       0.62745098, 0.7254902 , 0.74509804, 0.82352941, 0.84313725,
       0.8627451 , 0.88235294, 0.94117647, 0.96078431, 0.98039216,
       1.        ])
```

Step 8: Find the element in F with the closest absolute value to 0.25 and print it on screen.

[16]:
```
# first minus all elements in F by 0.25, take the absolute values, then find␣
 ↪the smallest number
# and its index, which corresponds to the element in F with the closest␣
 ↪absolute value to 0.25
Z = abs(F - 0.25)
min_value = Z.min()
min_index = list(Z).index(min_value)
print("The element in F with the closest absolute value to 0.25 is",␣
 ↪F[min_index], ".")
```

```
The element in F with the closest absolute value to 0.25 is 0.2549019607843137 .
```

6 PART III: TensorFlow Basics: TensorFlow Variables, Constants, Graph, Session, and Optimizers

Part III - 6 pts * (6 pts) Include screenshots of the following: * Run the master script to call five simple Python functions, and show that it works correctly. Show the value of loss function as a plot. (1 pt x 5) * Include your source code of five Python functions. Without this source code you will not receive any points for Part III!

[17]:
```
from __future__ import print_function
import numpy as np
import random
import sys
from functools import reduce
import tensorflow.compat.v1 as tf
tf.disable_v2_behavior()
import initializeX
import lossFunction
import optimizerFunction
import computeLoss
import trainStep
# import plotFunction

# Preliminary setup, do not modify
if len(sys.argv) > 1:
    # Since in my note book, sys.argv returns:
    # ['/Users/yuchengjin/anaconda3/lib/python3.7/site-packages/
 ↪ipykernel_launcher.py',
    # '-f',
    # '/Users/yuchengjin/Library/Jupyter/runtime/
 ↪kernel-b0d84050-0454-4670-bf1d-ec676d110f35.json']
    # and it will lead to the fault that '-f' could not be converted to int, so␣
 ↪I just comment
    # random.seed(int(sys.argv[1])) and np.random.seed(int(sys.argv[1])), and␣
 ↪change them to
    # random.seed(int(1)) and np.random.seed(int(1)), whiche is exactly what␣
 ↪happens in the terminal
    # random.seed(int(sys.argv[1]))
    # np.random.seed(int(sys.argv[1]))
    random.seed(int(1));
    np.random.seed(int(1));
else:
    random.seed(int(1));
    np.random.seed(int(1));

def shape(V):
    return list(map(int, list(V.shape)));

total = lambda shape : reduce(lambda x, y : x * y, shape, 1);
assert(total([3,4,1]) == 12);
# Preliminary setup over

#1. Create the constant a
```

```
a = tf.constant(10, dtype=tf.float32);

#2. Create the variable X. Here, recommended that you initialize X
# from a numpy array with random numbers selected from between 0 and 1.
X = initializeX.function(shape=(4,1));

shapeOfX = shape(X);
if not ((len(shapeOfX) == 2) and (shapeOfX[0] == 4) and (shapeOfX[1] == 1)):
    raise ValueError("Variable X doesn't have the correct shape");
else:
    print("X of correct shape has been returned");

#3. Create the constant b
b = tf.constant(np.arange(4).reshape((4,1)), dtype=tf.float32);

#3. Create the constant y
y = tf.constant(15, dtype=tf.float32);

#4. Create the tensorflow computation graph. The graph outputs
# the loss function that was described above. The function you
# write must evaluate (a(X^t*X) + b^t*X - y) ** 2
loss = lossFunction.function(a, X, b, y);

shapeOfLoss = shape(loss);
print("Loss has shape", shapeOfLoss);
assert(total(shapeOfLoss) == 1), "Loss is not a scalar!";

#5. Create the AdamOptimizer. Optimizers add additional nodes
# in the tensorflow graph to compute gradients as well as apply them to the␣
 ↪variables involved.
# This could be manually performed using tf.gradients etc, but it is a process␣
 ↪that is repeated
# over and over in all Deep Neural Networks, so the optimizers hide all the␣
 ↪gory details.
# In addition, optimizers do things other than calculate simple gradients in␣
 ↪order to ensure
# that convergence happens quickly. "Executing" the optimizer inside a tf.
 ↪Session hence implements
# 1) computation of gradients with respect to all the variables in the graph,␣
 ↪and 2) adjusting the value
# of the variables using these gradients
optimizer = optimizerFunction.function(loss, lr=1e-3);

#6. Launch the training loop. We want to track the loss function over the␣
 ↪training iterations
# We will launch 250 training iterations
```

```python
session = tf.Session();
session.run(tf.global_variables_initializer());

lossValues = [];

for i in range(250):
    # 7. Implement a function that provides the printable value of loss
    lossValue = computeLoss.function(session, loss);

    # 8. Implement a function that performs loss minimization
    trainStep.function(session, optimizer);

    # 9. Print out loss
    print("Iteration %d, loss = %f"%(i, lossValue));

    lossValues.append(lossValue);

### Please note that the following is not for demo, but only for the report␣
 ↪(hence, currently commented out)
# You may prepare the plot using another tool like Excel, but this is the␣
 ↪recommended way.
# # 10. Finally, add a function to plot the loss value across training steps
# # Please refer to the python library, pyplot https://matplotlib.org/users/
 ↪pyplot_tutorial.html
# plotFunction.function(lossValues);
```

```
X of correct shape has been returned
Loss has shape [1, 1]
Iteration 0, loss = 30.588102
Iteration 1, loss = 30.203985
Iteration 2, loss = 29.821484
Iteration 3, loss = 29.440592
Iteration 4, loss = 29.061388
Iteration 5, loss = 28.683916
Iteration 6, loss = 28.308212
Iteration 7, loss = 27.934328
Iteration 8, loss = 27.562300
Iteration 9, loss = 27.192148
Iteration 10, loss = 26.823956
Iteration 11, loss = 26.457745
Iteration 12, loss = 26.093571
Iteration 13, loss = 25.731449
Iteration 14, loss = 25.371433
Iteration 15, loss = 25.013582
Iteration 16, loss = 24.657894
Iteration 17, loss = 24.304441
Iteration 18, loss = 23.953224
```

```
Iteration 19, loss = 23.604332
Iteration 20, loss = 23.257759
Iteration 21, loss = 22.913549
Iteration 22, loss = 22.571724
Iteration 23, loss = 22.232359
Iteration 24, loss = 21.895441
Iteration 25, loss = 21.561007
Iteration 26, loss = 21.229101
Iteration 27, loss = 20.899754
Iteration 28, loss = 20.572971
Iteration 29, loss = 20.248808
Iteration 30, loss = 19.927252
Iteration 31, loss = 19.608353
Iteration 32, loss = 19.292145
Iteration 33, loss = 18.978632
Iteration 34, loss = 18.667835
Iteration 35, loss = 18.359793
Iteration 36, loss = 18.054491
Iteration 37, loss = 17.751984
Iteration 38, loss = 17.452261
Iteration 39, loss = 17.155359
Iteration 40, loss = 16.861280
Iteration 41, loss = 16.570038
Iteration 42, loss = 16.281662
Iteration 43, loss = 15.996155
Iteration 44, loss = 15.713529
Iteration 45, loss = 15.433810
Iteration 46, loss = 15.156983
Iteration 47, loss = 14.883074
Iteration 48, loss = 14.612084
Iteration 49, loss = 14.344039
Iteration 50, loss = 14.078920
Iteration 51, loss = 13.816755
Iteration 52, loss = 13.557547
Iteration 53, loss = 13.301286
Iteration 54, loss = 13.047980
Iteration 55, loss = 12.797642
Iteration 56, loss = 12.550262
Iteration 57, loss = 12.305873
Iteration 58, loss = 12.064442
Iteration 59, loss = 11.825994
Iteration 60, loss = 11.590504
Iteration 61, loss = 11.357985
Iteration 62, loss = 11.128441
Iteration 63, loss = 10.901856
Iteration 64, loss = 10.678245
Iteration 65, loss = 10.457592
Iteration 66, loss = 10.239889
```

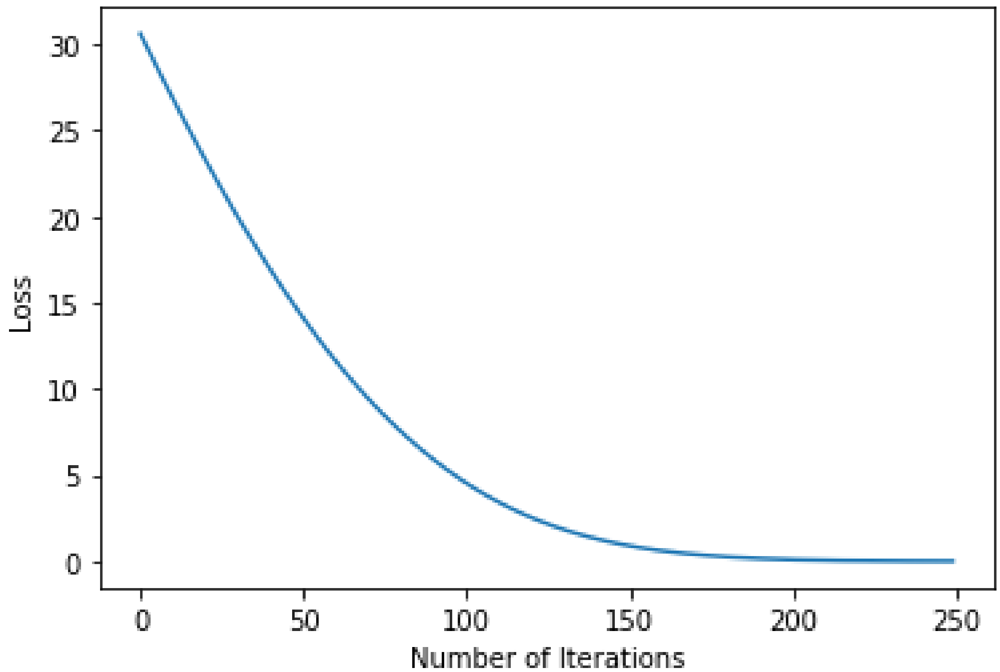
```
Iteration 67, loss = 10.025146
Iteration 68, loss = 9.813343
Iteration 69, loss = 9.604481
Iteration 70, loss = 9.398549
Iteration 71, loss = 9.195549
Iteration 72, loss = 8.995469
Iteration 73, loss = 8.798285
Iteration 74, loss = 8.604014
Iteration 75, loss = 8.412637
Iteration 76, loss = 8.224128
Iteration 77, loss = 8.038490
Iteration 78, loss = 7.855710
Iteration 79, loss = 7.675787
Iteration 80, loss = 7.498686
Iteration 81, loss = 7.324404
Iteration 82, loss = 7.152932
Iteration 83, loss = 6.984258
Iteration 84, loss = 6.818352
Iteration 85, loss = 6.655209
Iteration 86, loss = 6.494809
Iteration 87, loss = 6.337139
Iteration 88, loss = 6.182178
Iteration 89, loss = 6.029910
Iteration 90, loss = 5.880321
Iteration 91, loss = 5.733383
Iteration 92, loss = 5.589088
Iteration 93, loss = 5.447407
Iteration 94, loss = 5.308323
Iteration 95, loss = 5.171814
Iteration 96, loss = 5.037862
Iteration 97, loss = 4.906446
Iteration 98, loss = 4.777541
Iteration 99, loss = 4.651129
Iteration 100, loss = 4.527180
Iteration 101, loss = 4.405677
Iteration 102, loss = 4.286597
Iteration 103, loss = 4.169915
Iteration 104, loss = 4.055604
Iteration 105, loss = 3.943647
Iteration 106, loss = 3.834011
Iteration 107, loss = 3.726672
Iteration 108, loss = 3.621601
Iteration 109, loss = 3.518787
Iteration 110, loss = 3.418184
Iteration 111, loss = 3.319787
Iteration 112, loss = 3.223556
Iteration 113, loss = 3.129462
Iteration 114, loss = 3.037481
```

```
Iteration 115, loss = 2.947591
Iteration 116, loss = 2.859761
Iteration 117, loss = 2.773962
Iteration 118, loss = 2.690164
Iteration 119, loss = 2.608341
Iteration 120, loss = 2.528471
Iteration 121, loss = 2.450511
Iteration 122, loss = 2.374453
Iteration 123, loss = 2.300254
Iteration 124, loss = 2.227887
Iteration 125, loss = 2.157327
Iteration 126, loss = 2.088542
Iteration 127, loss = 2.021506
Iteration 128, loss = 1.956193
Iteration 129, loss = 1.892566
Iteration 130, loss = 1.830600
Iteration 131, loss = 1.770272
Iteration 132, loss = 1.711544
Iteration 133, loss = 1.654393
Iteration 134, loss = 1.598791
Iteration 135, loss = 1.544708
Iteration 136, loss = 1.492114
Iteration 137, loss = 1.440982
Iteration 138, loss = 1.391285
Iteration 139, loss = 1.342995
Iteration 140, loss = 1.296081
Iteration 141, loss = 1.250517
Iteration 142, loss = 1.206273
Iteration 143, loss = 1.163328
Iteration 144, loss = 1.121651
Iteration 145, loss = 1.081213
Iteration 146, loss = 1.041987
Iteration 147, loss = 1.003952
Iteration 148, loss = 0.967076
Iteration 149, loss = 0.931332
Iteration 150, loss = 0.896700
Iteration 151, loss = 0.863152
Iteration 152, loss = 0.830658
Iteration 153, loss = 0.799200
Iteration 154, loss = 0.768747
Iteration 155, loss = 0.739280
Iteration 156, loss = 0.710772
Iteration 157, loss = 0.683197
Iteration 158, loss = 0.656533
Iteration 159, loss = 0.630763
Iteration 160, loss = 0.605854
Iteration 161, loss = 0.581787
Iteration 162, loss = 0.558544
```

```
Iteration 163, loss = 0.536098
Iteration 164, loss = 0.514427
Iteration 165, loss = 0.493511
Iteration 166, loss = 0.473333
Iteration 167, loss = 0.453867
Iteration 168, loss = 0.435096
Iteration 169, loss = 0.416998
Iteration 170, loss = 0.399557
Iteration 171, loss = 0.382750
Iteration 172, loss = 0.366558
Iteration 173, loss = 0.350967
Iteration 174, loss = 0.335953
Iteration 175, loss = 0.321506
Iteration 176, loss = 0.307601
Iteration 177, loss = 0.294224
Iteration 178, loss = 0.281362
Iteration 179, loss = 0.268993
Iteration 180, loss = 0.257105
Iteration 181, loss = 0.245681
Iteration 182, loss = 0.234705
Iteration 183, loss = 0.224165
Iteration 184, loss = 0.214045
Iteration 185, loss = 0.204331
Iteration 186, loss = 0.195009
Iteration 187, loss = 0.186064
Iteration 188, loss = 0.177487
Iteration 189, loss = 0.169262
Iteration 190, loss = 0.161377
Iteration 191, loss = 0.153823
Iteration 192, loss = 0.146585
Iteration 193, loss = 0.139652
Iteration 194, loss = 0.133013
Iteration 195, loss = 0.126659
Iteration 196, loss = 0.120578
Iteration 197, loss = 0.114758
Iteration 198, loss = 0.109193
Iteration 199, loss = 0.103872
Iteration 200, loss = 0.098785
Iteration 201, loss = 0.093923
Iteration 202, loss = 0.089278
Iteration 203, loss = 0.084841
Iteration 204, loss = 0.080605
Iteration 205, loss = 0.076561
Iteration 206, loss = 0.072701
Iteration 207, loss = 0.069017
Iteration 208, loss = 0.065505
Iteration 209, loss = 0.062155
Iteration 210, loss = 0.058961
```

```
Iteration 211, loss = 0.055917
Iteration 212, loss = 0.053017
Iteration 213, loss = 0.050255
Iteration 214, loss = 0.047624
Iteration 215, loss = 0.045120
Iteration 216, loss = 0.042736
Iteration 217, loss = 0.040469
Iteration 218, loss = 0.038311
Iteration 219, loss = 0.036259
Iteration 220, loss = 0.034309
Iteration 221, loss = 0.032454
Iteration 222, loss = 0.030693
Iteration 223, loss = 0.029020
Iteration 224, loss = 0.027431
Iteration 225, loss = 0.025922
Iteration 226, loss = 0.024490
Iteration 227, loss = 0.023130
Iteration 228, loss = 0.021842
Iteration 229, loss = 0.020619
Iteration 230, loss = 0.019460
Iteration 231, loss = 0.018360
Iteration 232, loss = 0.017319
Iteration 233, loss = 0.016333
Iteration 234, loss = 0.015398
Iteration 235, loss = 0.014514
Iteration 236, loss = 0.013677
Iteration 237, loss = 0.012885
Iteration 238, loss = 0.012135
Iteration 239, loss = 0.011426
Iteration 240, loss = 0.010755
Iteration 241, loss = 0.010122
Iteration 242, loss = 0.009523
Iteration 243, loss = 0.008957
Iteration 244, loss = 0.008422
Iteration 245, loss = 0.007917
Iteration 246, loss = 0.007441
Iteration 247, loss = 0.006992
Iteration 248, loss = 0.006568
Iteration 249, loss = 0.006168
```

[29]:
```
import plotFunction
plotFunction.function(lossValues)
```



7 PART IV: Building CNN and Training

https://colab.research.google.com/drive/1MCXCnRyy2TOcZwABKQ83Vm_tzYVHrpIi

Part IV - 10 pts * Provide link to your Google Colaboratory Notebook that implements the code for this part. Grader will run your code to verify your results. Without the link to you your Google Colaboratory Notebook you will not receive any points for Part IV! Your Notebook should include the code to plot the loss function value vs epoch curve during the training. * (5 pts) Show the loss function value vs epoch curve during the training of CNN built with Keras. The final accuracy should be higher than 85%. * NOTE: Accuracy below 85% will result in points deduction (80 ~ 85%: -1 point; below 80%: -2 points). * Report the final accuracy of your Keras model. Plot the loss function value vs epoch curve during the training. * (5 pts) Show the loss function value vs epoch curve during the training of CNN built without Keras. The final accuracy should be higher than 85%. * NOTE: Accuracy below 85% will result in points deduction (80 ~ 85%: -1 point; below 80%: -2 points). * Report the final accuracy of your low-level API model. Plot the loss function value vs epoch curve during the training.

[19]:
```
from __future__ import absolute_import, division, print_function,␣
 ↪unicode_literals
import matplotlib.pyplot as plt
import tensorflow.compat.v1 as tf
tf.disable_v2_behavior()
from tensorflow.compat.v1 import keras
import numpy as np
import h5py
```

```python
# import data
fashion_mnist = keras.datasets.fashion_mnist
(train_images, train_labels), (test_images, test_labels) = fashion_mnist.
 ↪load_data()

# label data
class_names = ['T-shirt/top', 'Trouser', 'Pullover', 'Dress', 'Coat',
               'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot']

# preprocess data
train_images = train_images / 255.0
test_images = test_images / 255.0

# visualize data
plt.figure(figsize=(10,10))
for i in range(25):
    plt.subplot(5,5,i+1)
    plt.xticks([])
    plt.yticks([])
    plt.grid(False)
    plt.imshow(train_images[i], cmap=plt.cm.binary)
    plt.xlabel(class_names[train_labels[i]])
plt.show()
```

Keras

[89]:
```python
# build CNN model
CNN_model = keras.Sequential([
    # convolution layer; 5x5 filter, stride = 1, no padding; ReLU; output = (3, 24, 24)
    keras.layers.Conv2D(filters=20, kernel_size=(5,5), strides=1, padding='valid', activation='relu', input_shape=(28, 28, 1)),
    # max pooling layer; strides = 2; output = (3, 12, 12)
    keras.layers.MaxPooling2D(strides=2),
    # convolution layer; 3x3 filter, stride = 1, with padding; ReLU; output = (3, 12, 12)
    keras.layers.Conv2D(filters=20, kernel_size=(3,3), strides=1, padding='same', activation='relu', input_shape=(12, 12, 3)),
```

```
    # max pooling layer; strides = 2; output = (3, 6, 6)
    keras.layers.MaxPooling2D(strides=2),
    # flatten
    keras.layers.Flatten(),
    # fully connected layer; input size = 108, output size = 100; ReLU; output␣
 ↪= (100, 1, 1)
    keras.layers.Dense(units=100, activation='relu'),
    # fully connected layer; input size = 100, output size = 75; ReLU; output =␣
 ↪(75, 1, 1)
    keras.layers.Dense(units=75, activation='relu'),
    # fully connected layer; input size = 75, output size = 50; ReLU; output =␣
 ↪(50, 1, 1)
    keras.layers.Dense(units=50, activation='relu'),
    # fully connected layer; input size = 50, output size = 25; ReLU; output =␣
 ↪(25, 1, 1)
    keras.layers.Dense(units=25, activation='relu'),
    # fully connected layer; input size = 25, output size = 20; ReLU; output =␣
 ↪(20, 1, 1)
    keras.layers.Dense(units=20, activation='relu'),
    # fully connected layer; input size = 20, output size = 15; ReLU; output =␣
 ↪(15, 1, 1)
    keras.layers.Dense(units=15, activation='relu'),
    # fully connected layer; input size = 15, output size = 10; Softmax; output␣
 ↪= (10, 1, 1)
    keras.layers.Dense(units=10, activation='softmax'),
])

# compile CNN model
CNN_model.compile(loss="sparse_categorical_crossentropy", optimizer='adam',␣
 ↪metrics=['accuracy'])

# train CNN model
trained_model = CNN_model.fit(train_images.reshape(60000, 28, 28, 1),␣
 ↪train_labels, epochs=10)

# save the trained model
CNN_model.save('Keras_trained_model.h5')

# evaluate accuracy
test_loss, test_acc = CNN_model.evaluate(test_images.reshape(10000, 28, 28, 1),␣
 ↪test_labels, verbose=2)
```

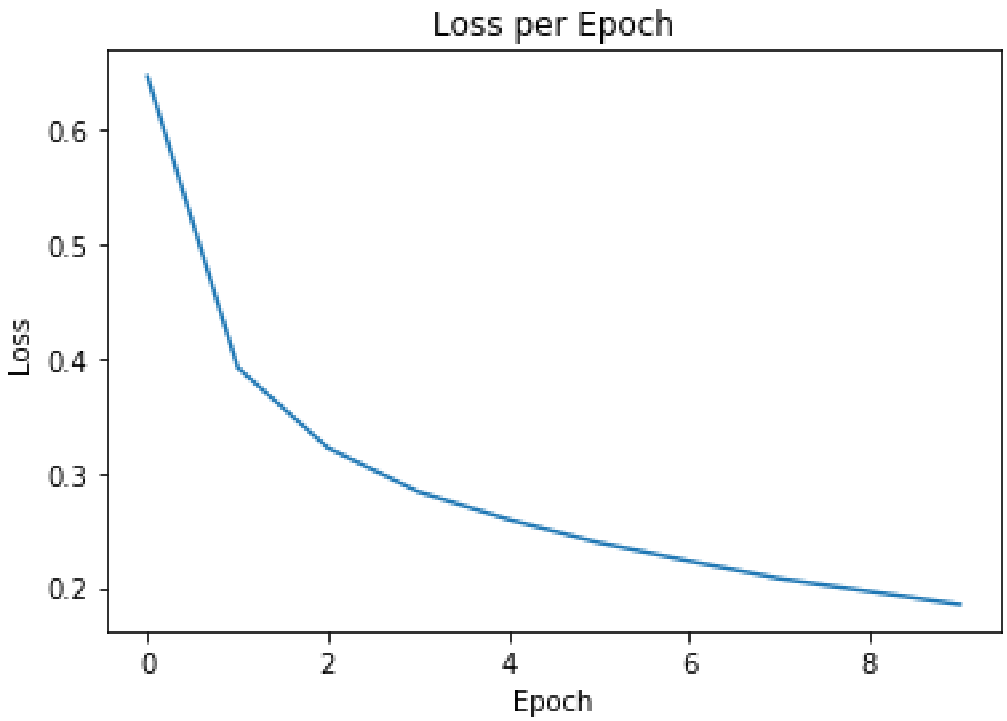
```
Train on 60000 samples
Epoch 1/10
60000/60000 [==============================] - 27s 453us/sample - loss: 0.6463 -
acc: 0.7500
Epoch 2/10
```

```
60000/60000 [==============================] - 26s 433us/sample - loss: 0.3922 -
acc: 0.8555
Epoch 3/10
60000/60000 [==============================] - 25s 423us/sample - loss: 0.3220 -
acc: 0.8819
Epoch 4/10
60000/60000 [==============================] - 26s 435us/sample - loss: 0.2835 -
acc: 0.8952
Epoch 5/10
60000/60000 [==============================] - 28s 461us/sample - loss: 0.2593 -
acc: 0.9038
Epoch 6/10
60000/60000 [==============================] - 27s 444us/sample - loss: 0.2390 -
acc: 0.9107
Epoch 7/10
60000/60000 [==============================] - 26s 430us/sample - loss: 0.2230 -
acc: 0.9183
Epoch 8/10
60000/60000 [==============================] - 28s 470us/sample - loss: 0.2078 -
acc: 0.9235
Epoch 9/10
60000/60000 [==============================] - 25s 424us/sample - loss: 0.1967 -
acc: 0.9269
Epoch 10/10
60000/60000 [==============================] - 25s 413us/sample - loss: 0.1853 -
acc: 0.9310
10000/10000 - 2s - loss: 0.2760 - acc: 0.9069
```

[90]:
```
print('\nTest accuracy:', test_acc)
```

```
Test accuracy: 0.9069
```

[91]:
```
plt.plot(trained_model.history['loss'])
plt.title('Loss per Epoch')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.show()
```



[92]:
```
# recreate the exact same model, including its weights and the optimizer
new_model = tf.keras.models.load_model('Keras_trained_model.h5')
# show the model architecture
new_model.summary()
```

```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_12 (Conv2D)           (None, 24, 24, 20)        520
_________________________________________________________________
max_pooling2d_12 (MaxPooling (None, 12, 12, 20)        0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 12, 12, 20)        3620
_________________________________________________________________
max_pooling2d_13 (MaxPooling (None, 6, 6, 20)          0
_________________________________________________________________
flatten_6 (Flatten)          (None, 720)               0
_________________________________________________________________
dense_32 (Dense)             (None, 100)               72100
_________________________________________________________________
dense_33 (Dense)             (None, 75)                7575
_________________________________________________________________
dense_34 (Dense)             (None, 50)                3800
```

```
_________________________________________________________________
dense_35 (Dense)             (None, 25)                1275
_________________________________________________________________
dense_36 (Dense)             (None, 20)                520
_________________________________________________________________
dense_37 (Dense)             (None, 15)                315
_________________________________________________________________
dense_38 (Dense)             (None, 10)                160
=================================================================
Total params: 89,885
Trainable params: 89,885
Non-trainable params: 0
_________________________________________________________________
```

Low-Level API

[30]:
```python
import tensorflow.compat.v1 as tf
tf.disable_v2_behavior()
from tensorflow.examples.tutorials.mnist import input_data
mnist = input_data.read_data_sets("/tmp/data/", one_hot=True)
tf.reset_default_graph()
```

```
Extracting /tmp/data/train-images-idx3-ubyte.gz
Extracting /tmp/data/train-labels-idx1-ubyte.gz
Extracting /tmp/data/t10k-images-idx3-ubyte.gz
Extracting /tmp/data/t10k-labels-idx1-ubyte.gz
```

[31]:
```python
# Training Parameters
learning_rate = 0.001
batch_size = 128
num_steps = int(60000/batch_size)
display_step = 10

# Network Parameters
num_input = 784 # MNIST data input (img shape: 28*28)
num_classes = 10 # MNIST total classes (0-9 digits)

# tf Graph input
X = tf.placeholder(tf.float32, [None, num_input])
Y = tf.placeholder(tf.float32, [None, num_classes])
keep_prob = tf.placeholder(tf.float32) # dropout (keep probability)
```

[32]:
```python
# Create some wrappers for simplicity
def conv2d(x, W, b, strides=1, padding='SAME'):
    # Conv2D wrapper, with bias and relu activation
    x = tf.nn.conv2d(x, W, strides=[1, strides, strides, 1], padding=padding)
    x = tf.nn.bias_add(x, b)
    return tf.nn.relu(x)
```

```
def maxpool2d(x, k=2):
    # MaxPool2D wrapper
    return tf.nn.max_pool(x, ksize=[1, k, k, 1], strides=[1, k, k, 1],
                          padding='SAME')

# Create model
def conv_net(x, weights, biases, dropout):
    # MNIST data input is a 1-D vector of 784 features (28*28 pixels)
    # Reshape to match picture format [Height x Width x Channel]
    # Tensor input become 4-D: [Batch Size, Height, Width, Channel]
    x = tf.reshape(x, shape=[-1, 28, 28, 1])

    # Convolution layer; 5x5 filter, stride = 1, no padding; ReLU; output = (3,␣
 ↪24, 24)
    conv1 = conv2d(x, weights['wc1'], biases['bc1'], padding='VALID')
    # Max pooling layer; strides = 2; output = (3, 12, 12)
    conv1 = maxpool2d(conv1, k=2)

    # Convolution layer; 3x3 filter, stride = 1, with padding; ReLU; output =␣
 ↪(3, 12, 12)
    conv2 = conv2d(conv1, weights['wc2'], biases['bc2'], padding='SAME')
    # Max pooling layer; strides = 2; output = (3, 6, 6)
    conv2 = maxpool2d(conv2, k=2)

    # Flatten
    fl1 = tf.reshape(conv2, [-1,108])

    # Fully connected layer
    # Reshape conv2 output to fit fully connected layer input
    # Fully connected layer; input size = 108, output size = 100; ReLU; output␣
 ↪= (100, 1, 1)
    fc1 = tf.add(tf.matmul(fl1, weights['wd1']), biases['bd1'])
    fc1 = tf.nn.relu(fc1)
    # Fully connected layer; input size = 100, output size = 50; ReLU; output =␣
 ↪(50, 1, 1)
    fc2 = tf.add(tf.matmul(fc1, weights['wd2']), biases['bd2'])
    fc2 = tf.nn.relu(fc2)
    # Fully connected layer; input size = 50, output size = 10; Softmax; output␣
 ↪= (10, 1, 1)
    fc3 = tf.add(tf.matmul(fc2, weights['wd3']), biases['bd3'])

    return fc3
```

[33]:
```
# Store layers weight & bias
weights = {
    # 3x1x5x5
```

```
    'wc1': tf.get_variable("W0", shape=[5, 5, 1, 3]),
    # 3x3x3x3
    'wc2': tf.get_variable("W1", shape=[3, 3, 3, 3]),
    # 108x100
    'wd1': tf.get_variable("W2", shape=[108, 100]),
    # 100x50
    'wd2': tf.get_variable("W3", shape=[100, 50]),
    # 50x10
    'wd3': tf.get_variable("W4", shape=[50, 10])
}

biases = {
    'bc1': tf.get_variable("B0", shape=[3], initializer=tf.zeros_initializer()),
    'bc2': tf.get_variable("B1", shape=[3], initializer=tf.zeros_initializer()),
    'bd1': tf.get_variable("B2", shape=[100], initializer=tf.
 ↪zeros_initializer()),
    'bd2': tf.get_variable("B3", shape=[50], initializer=tf.
 ↪zeros_initializer()),
    'bd3': tf.get_variable("B4", shape=[10], initializer=tf.zeros_initializer())
}

# Construct model
logits = conv_net(X, weights, biases, keep_prob)
prediction = tf.nn.softmax(logits)

# Define loss and optimizer
loss_op = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(
    logits=logits, labels=Y))
optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate)
train_op = optimizer.minimize(loss_op)

# Evaluate model
correct_pred = tf.equal(tf.argmax(prediction, 1), tf.argmax(Y, 1))
accuracy = tf.reduce_mean(tf.cast(correct_pred, tf.float32))

# Initialize the variables (i.e. assign their default value)
init = tf.global_variables_initializer()
```

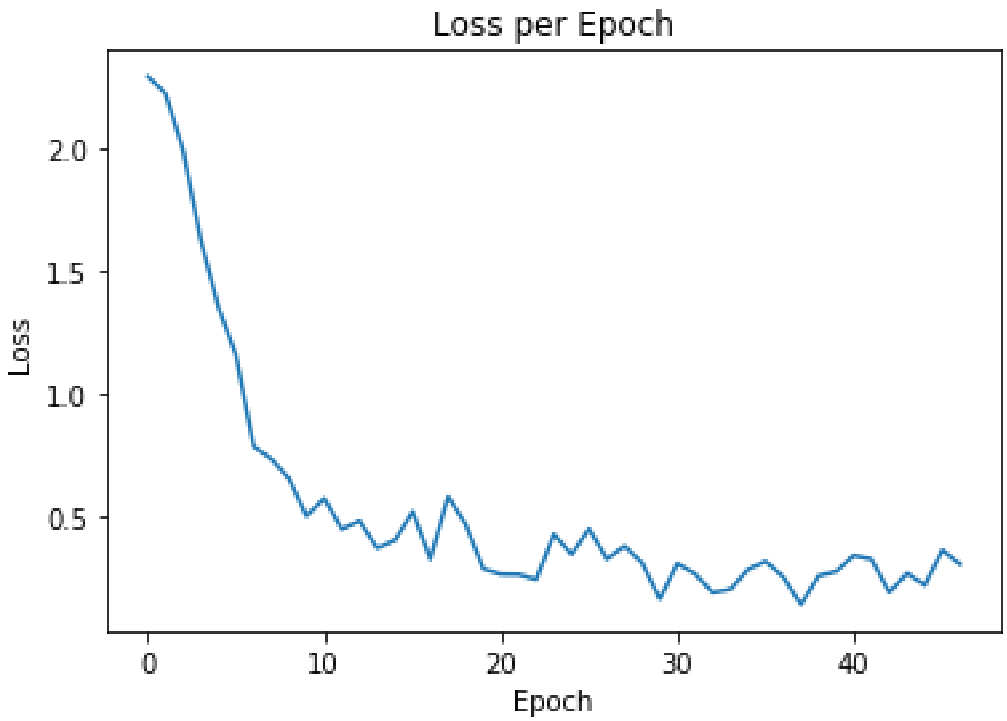
[46]:
```
loss_val = []

# Start training
with tf.Session() as sess:

    # Run the initializer
    sess.run(init)

    for step in range(1, num_steps+1):
```

```
        batch_x, batch_y = mnist.train.next_batch(batch_size)
        # Run optimization op (backprop)
        sess.run(train_op, feed_dict={X: batch_x, Y: batch_y, keep_prob: 1.0})
        if step % display_step == 0 or step == 1:
            # Calculate batch loss and accuracy
            loss, acc = sess.run([loss_op, accuracy], feed_dict={X: batch_x,
                                                                 Y: batch_y,
                                                                 keep_prob: 1.
↪0})
            print("Step " + str(step) + ", Minibatch Loss= " + \
                  "{:.4f}".format(loss) + ", Training Accuracy= " + \
                  "{:.3f}".format(acc))

            loss_val.append(loss)

    print("Optimization Finished!")

    # Calculate accuracy for 256 MNIST test images
    print("Testing Accuracy:", \
        sess.run(accuracy, feed_dict={X: mnist.test.images[:256],
                                      Y: mnist.test.labels[:256],
                                      keep_prob: 1.0}))
```

```
Step 1, Minibatch Loss= 2.2923, Training Accuracy= 0.109
Step 10, Minibatch Loss= 2.2230, Training Accuracy= 0.297
Step 20, Minibatch Loss= 1.9929, Training Accuracy= 0.391
Step 30, Minibatch Loss= 1.6280, Training Accuracy= 0.492
Step 40, Minibatch Loss= 1.3536, Training Accuracy= 0.641
Step 50, Minibatch Loss= 1.1571, Training Accuracy= 0.648
Step 60, Minibatch Loss= 0.7868, Training Accuracy= 0.766
Step 70, Minibatch Loss= 0.7359, Training Accuracy= 0.742
Step 80, Minibatch Loss= 0.6559, Training Accuracy= 0.836
Step 90, Minibatch Loss= 0.5019, Training Accuracy= 0.820
Step 100, Minibatch Loss= 0.5753, Training Accuracy= 0.836
Step 110, Minibatch Loss= 0.4496, Training Accuracy= 0.883
Step 120, Minibatch Loss= 0.4831, Training Accuracy= 0.883
Step 130, Minibatch Loss= 0.3720, Training Accuracy= 0.898
Step 140, Minibatch Loss= 0.4052, Training Accuracy= 0.883
Step 150, Minibatch Loss= 0.5206, Training Accuracy= 0.828
Step 160, Minibatch Loss= 0.3269, Training Accuracy= 0.930
Step 170, Minibatch Loss= 0.5827, Training Accuracy= 0.844
Step 180, Minibatch Loss= 0.4686, Training Accuracy= 0.875
Step 190, Minibatch Loss= 0.2877, Training Accuracy= 0.914
Step 200, Minibatch Loss= 0.2663, Training Accuracy= 0.945
Step 210, Minibatch Loss= 0.2653, Training Accuracy= 0.914
Step 220, Minibatch Loss= 0.2455, Training Accuracy= 0.938
Step 230, Minibatch Loss= 0.4284, Training Accuracy= 0.891
```

```
Step 240, Minibatch Loss= 0.3469, Training Accuracy= 0.898
Step 250, Minibatch Loss= 0.4513, Training Accuracy= 0.875
Step 260, Minibatch Loss= 0.3271, Training Accuracy= 0.922
Step 270, Minibatch Loss= 0.3806, Training Accuracy= 0.906
Step 280, Minibatch Loss= 0.3119, Training Accuracy= 0.922
Step 290, Minibatch Loss= 0.1667, Training Accuracy= 0.953
Step 300, Minibatch Loss= 0.3098, Training Accuracy= 0.883
Step 310, Minibatch Loss= 0.2674, Training Accuracy= 0.914
Step 320, Minibatch Loss= 0.1927, Training Accuracy= 0.938
Step 330, Minibatch Loss= 0.2055, Training Accuracy= 0.938
Step 340, Minibatch Loss= 0.2855, Training Accuracy= 0.930
Step 350, Minibatch Loss= 0.3186, Training Accuracy= 0.906
Step 360, Minibatch Loss= 0.2550, Training Accuracy= 0.930
Step 370, Minibatch Loss= 0.1439, Training Accuracy= 0.977
Step 380, Minibatch Loss= 0.2599, Training Accuracy= 0.914
Step 390, Minibatch Loss= 0.2773, Training Accuracy= 0.914
Step 400, Minibatch Loss= 0.3427, Training Accuracy= 0.914
Step 410, Minibatch Loss= 0.3270, Training Accuracy= 0.930
Step 420, Minibatch Loss= 0.1943, Training Accuracy= 0.938
Step 430, Minibatch Loss= 0.2702, Training Accuracy= 0.891
Step 440, Minibatch Loss= 0.2225, Training Accuracy= 0.930
Step 450, Minibatch Loss= 0.3633, Training Accuracy= 0.875
Step 460, Minibatch Loss= 0.3069, Training Accuracy= 0.898
Optimization Finished!
Testing Accuracy: 0.95703125
```

[47]:
```
plt.plot(loss_val)
plt.title('Loss per Epoch')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.show()
```



8 PART V: Deployment and Inference

Part V - 12 pts * Provide link to your Google Colaboratory Notebook that implements the code for this part of the lab. Grader will run your code to verify your results. Without the link to you your Google Colaboratory Notebook you will not receive any points for Part V! Your code must include the following components: * (2 pts) Request and get test datasets from the remote server correctly. * (4 pts) Run inference on the test dataset and generate prediction results. * (2 pts) Send your prediction results in POST request to the remote server. * (3 pts) Get the number of correct predictions from the remote server. The prediction accuracy should be higher than 85%. * (1 pt) Have code to request 5 test datasets from server and report the inference accuracies on these test datasets. * NOTE: Accuracy below 85% will result in points deduction (80 ~ 85%: -1 point; below 80%: -2 points).

[93]:
```
import requests
import gzip
import numpy as np
import tensorflow.compat.v1 as tf
tf.disable_v2_behavior()
from tensorflow.compat.v1 import keras
import numpy as np
import h5py

def get_testset():
```

```python
    url = 'https://courses.engr.illinois.edu/ece498icc/sp2020/
 ↪lab1_request_dataset.php'
    values = {'request': 'testdata', 'netid':'yucheng9'}
    r = requests.post(url, data=values, allow_redirects=True)
    filename = r.url.split("/")[-1]
    testset_id = filename.split(".")[0].split("_")[-1]
    with open(filename, 'wb') as f:
        f.write(r.content)
    return load_dataset(filename), testset_id

def load_dataset(path):
    num_img = 1000
    with gzip.open(path, 'rb') as infile:
        data = np.frombuffer(infile.read(), dtype=np.uint8).reshape(num_img,␣
 ↪784)
    return data

def verify_accuracy(testset_id, prediction):
    url = 'https://courses.engr.illinois.edu/ece498icc/sp2020/
 ↪lab1_request_dataset.php'
    values = {'request': 'verify', 'netid':'yucheng9',
              'testset_id':testset_id, 'prediction':prediction}
    r = requests.post(url, data=values, allow_redirects=True)

    return r.json()/1000.0

model = tf.keras.models.load_model('Keras_trained_model.h5')

for i in range(5):
    images,id = get_testset()
    predictions = ''
    for j in range(1000):
        test_image = images[j].reshape(1,28,28,1)
        prediction = model.predict_classes(test_image)
        predictions= predictions+str(prediction[0])

    print("Dataset ID:", id)
    print("The number of correct predictions:",␣
 ↪1000*verify_accuracy(id,predictions))
    print("Accuracy:", verify_accuracy(id,predictions))
```

```
Dataset ID: 9ed727df
The number of correct predictions: 873.0
Accuracy: 0.873
Dataset ID: 84ec9825
The number of correct predictions: 891.0
Accuracy: 0.891
```

```
Dataset ID: 32e4962e
The number of correct predictions: 861.0
Accuracy: 0.861
Dataset ID: 11d6c3d6
The number of correct predictions: 904.0
Accuracy: 0.904
Dataset ID: 4d6c5164
The number of correct predictions: 889.0
Accuracy: 0.889
```

9 Conclusion

- If you made any assumptions about the functionality of the system, please list and justify them
  - My tensorflow version is 2.0.0, I used tf.disable_v2_behavior() to run tf 1.x.x version.
  - In Part III, my sys.argv is ['/Users/yuchengjin/anaconda3/lib/python3.7/site packages/ipykernel_launcher.py', '-f', '/Users/yuchengjin/Library/Jupyter/runtime/kernel-b0d84050-0454-4670-bf1d-ec676d110f35.json'], with len(sys.argv) > 1, so I modified code a little bit to enable random seed.
- The difficulties/bugs you encountered and how you solved them
  - The most important difficulty is to improve the performance of my Keras CNN. The accuracy of my Keras CNN was pretty low with the original configuration, therefore, I added some dense layers, and increased the number of filters to solve this problem.
- What you learned from this lab
  - How to make HTTP request and receive information online.
  - Numpy and Tensorflow basics.
  - How to build up Keras and low-level CNN, and adjust parameters to improve their performance.