In [35]:

```
import os
import copy
import time
import shelve
import random
import numpy as np
import pandas as pd
import tensorflow as tf
from pandas import DataFrame
import matplotlib.pyplot as plt
```

In [36]:

```
def load_data(name):

    if name == 'mnist':
        (X_train, y_train), (X_test, y_test) = tf.keras.datasets.mnist.load_data()
    elif name == 'fashion_mnist':
        (X_train, y_train), (X_test, y_test) = tf.keras.datasets.fashion_mnist.loa
d_data()
    else:
        print('Only mnist or fashion_mnist.')
        return False

    imageSize  = X_train.shape[1]*X_train.shape[2]
    numClasses = np.max(y_train)+1

    X_train = np.reshape(X_train.astype(float)/255.0, (-1, 784))
    X_test  = np.reshape(X_test.astype(float)/255.0, (-1, 784))

    y_train = tf.keras.utils.to_categorical(y_train, num_classes=numClasses)
    y_test  = tf.keras.utils.to_categorical(y_test, num_classes=numClasses)

    X_val   = X_train[-10000:]
    y_val   = y_train[-10000:]
    X_train = X_train[:-10000]
    y_train = y_train[:-10000]

    print('Data Split: ')
    print(f'X_train: {X_train.shape}, y_train: {y_train.shape}')
    print(f'X_test : {X_test.shape }, y_test : {y_test.shape }')
    print(f'X_val  : {X_val.shape  }, y_val  : {y_val.shape  }')

    data = {}
    data['X_train'] = X_train
    data['y_train'] = y_train
    data['X_val']   = X_val
    data['y_val']   = y_val
    data['X_test']  = X_test
    data['y_test']  = y_test

    data['imageSize'] = imageSize

    return data
```

In [37]:

```
class myOptimizer():

    def __init__(self, var):

        self.m = [np.zeros(np.shape(i)) for i in var]
        self.v = [np.zeros(np.shape(i)) for i in var]
        self.u = [np.zeros(np.shape(i)) for i in var]

        self.alpha   = 5e-4
        self.beta    = [0.9, 0.999, 0.999987]
        self.epsilon = [1e-8, 1e-6]

    def updateWeights(self, t, grads, var):

        for i in range(np.shape(var)[0]):

            self.m[i] = (self.beta[0]*self.m[i]) + ((1 - self.beta[0])*grads[i])
            self.v[i] = (self.beta[1]*self.v[i]) + ((1 - self.beta[1])*(grads[i]*g
rads[i]))
            self.u[i] = (self.beta[2]*self.u[i]) + ((1 - self.beta[2])*(grads[i]*g
rads[i]*grads[i]))

            mHat = self.m[i]/(1-self.beta[0]**t)
            vHat = self.v[i]/(1-self.beta[1]**t)
            uHat = self.u[i]/(1-self.beta[2]**t)

            # delta = self.alpha*mHat/((tf.sign(vHat)*tf.sqrt(tf.abs(vHat)))+(tf.s
ign(uHat)*tf.math.pow(tf.abs(uHat), 1/3)*self.epsilon[0])+self.epsilon[0])
            delta = self.alpha * mHat / (tf.sqrt(vHat)+(tf.sign(uHat)*tf.math.pow(
tf.abs(uHat), 1/3)*self.epsilon[0] + self.epsilon[1]))
            var[i].assign(var[i] - delta)
```

In [38]:

```
class MLP(object):

    def __init__(self, name, size_input, size_hidden, size_output, learning_rate=
0.01, weight_coeff=1,\
                  Reg=None, RegC=0, training=None, validation=None, accuracy=0, de
vice=None):

        self.name          = name
        self.size_input    = size_input
        self.size_hidden   = size_hidden
        self.size_output   = size_output
        self.Reg           = Reg
        self.RegC          = RegC
        self.training      = training
        self.validation    = validation
        self.accuracy      = accuracy
        self.device        = device
        self.learning_rate = learning_rate
        self.weight_coeff  = weight_coeff

        self.W1 = self.initWeights(self.size_input, self.size_hidden[0], self.weig
ht_coeff)
        self.b1 = self.initWeights(1, self.size_hidden[0], self.weight_coeff)

        self.W2 = self.initWeights(self.size_hidden[0], self.size_hidden[1], self.
weight_coeff)
        self.b2 = self.initWeights(1, self.size_hidden[1], self.weight_coeff)

        self.W3 = self.initWeights(self.size_hidden[1], self.size_hidden[2], self.
weight_coeff)
        self.b3 = self.initWeights(1, self.size_hidden[2], self.weight_coeff)

        self.W4 = self.initWeights(self.size_hidden[2], self.size_output, self.wei
ght_coeff)
        self.b4 = self.initWeights(1, self.size_output, self.weight_coeff)

        self.variables = [self.W1, self.b1, self.W2, self.b2, self.W3, self.b3, se
lf.W4, self.b4]

        self.optimizer = myOptimizer(self.variables)

    def initWeights(self, rows, columns, multFactor=1):
        return tf.Variable(multFactor*tf.random.normal([rows, columns]))

    def forward(self, X):

        if self.device is not None:
            with tf.device('gpu:0' if self.device=='gpu' else 'cpu'):
                self.y = self.compute_output(X)
        else:
            self.y = self.compute_output(X)

        return self.y
    def getRegLoss(self, X_train):

        if self.Reg=='L2':
            return (self.RegC/X_train.shape[0])*(tf.reduce_sum(tf.math.square(self
.variables[0])) +
                                                 tf.reduce_sum(tf.math.square(self
.variables[2])) +
                                                 tf.reduce_sum(tf.math.square(self
.variables[4])) +
                                                 tf.reduce_sum(tf.math.square(self
.variables[6])))

        elif self.Reg=='L1':
            return (self.RegC/X_train.shape[0])*tf.abs(tf.reduce_sum(self.variable
s[0]) +
                                                       tf.reduce_sum(self.variable
s[2]) +
                                                       tf.reduce_sum(self.variable
s[4]) +
                                                       tf.reduce_sum(self.variable
s[6]))

        elif self.Reg=='L1+L2':
            L2 =  (self.RegC/X_train.shape[0])*(tf.reduce_sum(tf.math.square(self.
variables[0])) +
                                                tf.reduce_sum(tf.math.square(self.
variables[2])) +
                                                tf.reduce_sum(tf.math.square(self.
variables[4])) +
                                                tf.reduce_sum(tf.math.square(self.
variables[6])))

            L1 = (self.RegC/X_train.shape[0])*tf.abs(tf.reduce_sum(self.variables[
0]) +
                                                     tf.reduce_sum(self.variables[
2]) +
                                                     tf.reduce_sum(self.variables[
4]) +
                                                     tf.reduce_sum(self.variables[
6]))
            return L1+L2

        else:
            return 0

    def loss(self, y_pred, y_true):

        y_true_tf = tf.cast(tf.reshape(y_true, (-1, self.size_output)), dtype=tf.f
loat32)
        y_pred_tf = tf.cast(y_pred, dtype=tf.float32)

        loss = tf.keras.losses.CategoricalCrossentropy()(y_true_tf, y_pred_tf)
        return loss

    def backward(self, X_train, y_train, t):
        with tf.GradientTape() as tape:
            predicted = self.forward(X_train)
            current_loss = self.loss(predicted, y_train)
            current_loss += self.getRegLoss(X_train)

        grads = tape.gradient(current_loss, self.variables)
        self.optimizer.updateWeights(t, grads, self.variables)


    def compute_output(self, X):

        X_tf = tf.cast(X, dtype=tf.float32)

        w1Hat = tf.matmul(X_tf,  self.variables[0]) + self.variables[1]
        h1Hat = tf.nn.relu(w1Hat)

        w2Hat = tf.matmul(h1Hat, self.variables[2]) + self.variables[3]
        h2Hat = tf.nn.relu(w2Hat)

        w3Hat = tf.matmul(h2Hat, self.variables[4]) + self.variables[5]
        h3Hat = tf.nn.relu(w3Hat)

        w4Hat = tf.matmul(h3Hat, self.variables[6]) + self.variables[7]
        output = tf.nn.softmax(w4Hat)

        return output

    def getAccuracy(self, predictions, outputs):
        preds  = np.argmax(predictions, axis=1)
        y_true = np.argmax(outputs, axis=1)

        return (preds==y_true).mean()
```

In [39]:

```
def trainModel(model, data, NUM_EPOCHS=10, batchSize=50, seedVal=1234):

    X_train = data['X_train']
    y_train = data['y_train']
    X_val   = data['X_val']
    y_val   = data['y_val']

    training = np.zeros(shape=(NUM_EPOCHS, 3))
    validation = np.zeros(shape=(NUM_EPOCHS, 3))

    train_ds = tf.data.Dataset.from_tensor_slices((X_train, y_train)).batch(batchS
ize)
    val_ds   = tf.data.Dataset.from_tensor_slices((X_val, y_val)).batch(batchSize)

    print(f'\n\n**************** Training model: {model.name} with seed: {seedVal}
****************\n')
    time_start = time.time()
    for epoch in range(NUM_EPOCHS):
        train_loss = tf.zeros([1, 1], dtype=tf.float32)
        val_loss   = tf.zeros([1, 1], dtype=tf.float32)

        train_ds = tf.data.Dataset.from_tensor_slices((X_train, y_train)).shuffle(
25, seed = epoch*(seedVal)).batch(batchSize)
        val_ds   = tf.data.Dataset.from_tensor_slices((X_val, y_val)).shuffle(25,
seed = epoch*(seedVal)).batch(batchSize)

        t = 0
        for inputs, outputs in train_ds:
            t+=1
            train_pred = model.forward(inputs)
            train_loss = train_loss + model.loss(train_pred, outputs)
            model.backward(inputs, outputs, t)
            train_acc = model.getAccuracy(train_pred, outputs)

        for inputs, outputs in val_ds:
            val_pred = model.forward(inputs)
            val_loss = val_loss + model.loss(val_pred, outputs)
            val_acc  = model.getAccuracy(val_pred, outputs)

        # train_loss = np.array(train_loss)
        # val_loss = np.array(val_loss)

        training[epoch] = [epoch+1, train_acc, np.sum(train_loss)/X_train.shape[0
]]
        validation[epoch] = [epoch+1, val_acc, np.sum(train_loss)/X_train.shape[0
]]

        print('# Epoch:={}/{}  - train loss:={:.4f} - val loss:={:.4f}, train acc:
={:.2f} - val acc:={:.2f}'\
              .format(epoch+1, NUM_EPOCHS, np.sum(train_loss)/X_train.shape[0], np
.sum(val_loss)/X_val.shape[0], train_acc, val_acc))

    time_taken = time.time()-time_start
    print(f'\nTotal time taken (in seconds): {time_taken: .2f}')
    print(f'\nFinished training model: {model.name}\n')
    model.training = training
    model.validation = validation

def testModel(model, data):

    X_test = data['X_test']
    y_test = data['y_test']

    preds = model.forward(X_test)

    pred = np.argmax(preds, axis=1)
    y_true= np.argmax(y_test, axis=1)

    model.accuracy = (pred==y_true).mean()*100

    print(f'**************** Testing ****************')
    print(f'{model.name} model accuracy = {model.accuracy:.2f}%')
    print(f'*****************************************')

def plotAccuracyAndLoss(model):

    training = model.training
    validation = model.validation
    fig, (ax1, ax2) = plt.subplots(1, 2)
    training[:, -1] = training[:, -1]/np.linalg.norm(training[:, -1])
    ax1.plot(training[:,0], training[:,1], 'g')
    ax1.plot(training[:,0], training[:,2], 'b')
    ax1.set_title('Training')
    ax1.legend(["Accuracy", "Loss"])

    validation[:, -1] = validation[:, -1]/np.linalg.norm(validation[:, -1])
    ax2.plot(validation[:,0], validation[:,1], 'g')
    ax2.plot(validation[:,0], validation[:,2], 'b')
    ax2.set_title('Validation')
    ax2.legend(["Accuracy", "Loss"])
    plt.show()
```

In [50]:

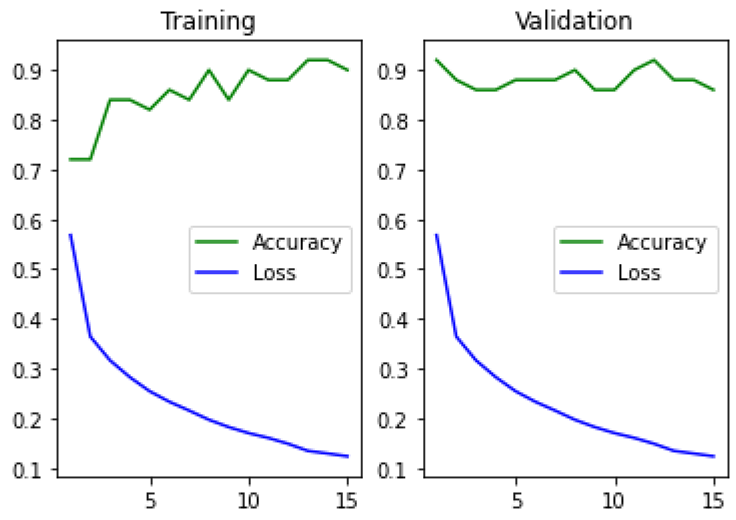
```
def main():

    data = load_data('fashion_mnist')

    imageSize = data['imageSize']

    size_input  = imageSize
    size_hidden = [1024, 512, 256]
    size_output = 10

    numEpochs = 15
    batchSize = 50

    learning_rate = 1e-4
    weight_coeff  = 0.1

    seeds = np.random.randint(1000, 9999)

    np.random.seed(seeds)
    tf.random.set_seed(seeds)

    model = MLP('mlp_on_gpu_default', size_input, size_hidden, size_output, learni
ng_rate=learning_rate,\
                weight_coeff=weight_coeff, device='gpu')

    trainModel(model, data, numEpochs, batchSize, seeds)
    testModel(model, data)
    plotAccuracyAndLoss(model)

    return model
```

In [51]:

```
if __name__ == "__main__":
    mnist = main()
```

```
Data Split:
X_train: (50000, 784), y_train: (50000, 10)
X_test : (10000, 784), y_test : (10000, 10)
X_val  : (10000, 784), y_val  : (10000, 10)


**************** Training model: mlp_on_gpu_default with seed: 4796 **
**************


/home/skanda/Softwares/miniconda3/lib/python3.9/site-packages/numpy/co
re/fromnumeric.py:1970: VisibleDeprecationWarning: Creating an ndarray
from ragged nested sequences (which is a list-or-tuple of lists-or-tup
les-or ndarrays with different lengths or shapes) is deprecated. If yo
u meant to do this, you must specify 'dtype=object' when creating the
ndarray.
  result = asarray(a).shape
```

```
# Epoch:=1/15  - train loss:=0.0104 - val loss:=0.0085, train acc:=0.7
2 - val acc:=0.92
# Epoch:=2/15  - train loss:=0.0067 - val loss:=0.0081, train acc:=0.7
2 - val acc:=0.88
# Epoch:=3/15  - train loss:=0.0058 - val loss:=0.0078, train acc:=0.8
4 - val acc:=0.86
# Epoch:=4/15  - train loss:=0.0052 - val loss:=0.0074, train acc:=0.8
4 - val acc:=0.86
# Epoch:=5/15  - train loss:=0.0047 - val loss:=0.0074, train acc:=0.8
2 - val acc:=0.88
# Epoch:=6/15  - train loss:=0.0043 - val loss:=0.0077, train acc:=0.8
6 - val acc:=0.88
# Epoch:=7/15  - train loss:=0.0039 - val loss:=0.0077, train acc:=0.8
4 - val acc:=0.88
# Epoch:=8/15  - train loss:=0.0036 - val loss:=0.0074, train acc:=0.9
0 - val acc:=0.90
# Epoch:=9/15  - train loss:=0.0033 - val loss:=0.0075, train acc:=0.8
4 - val acc:=0.86
# Epoch:=10/15  - train loss:=0.0031 - val loss:=0.0072, train acc:=0.
90 - val acc:=0.86
# Epoch:=11/15  - train loss:=0.0029 - val loss:=0.0076, train acc:=0.
88 - val acc:=0.90
# Epoch:=12/15  - train loss:=0.0027 - val loss:=0.0075, train acc:=0.
88 - val acc:=0.92
# Epoch:=13/15  - train loss:=0.0025 - val loss:=0.0080, train acc:=0.
92 - val acc:=0.88
# Epoch:=14/15  - train loss:=0.0024 - val loss:=0.0085, train acc:=0.
92 - val acc:=0.88
# Epoch:=15/15  - train loss:=0.0023 - val loss:=0.0085, train acc:=0.
90 - val acc:=0.86

Total time taken (in seconds):  315.32

Finished training model: mlp_on_gpu_default

**************** Testing ****************
mlp_on_gpu_default model accuracy = 87.52%
*****************************************
```



In [ ]:

```
```