

1d_NN_example

December 2, 2018

1 Investigating the failure of convergence of neural networks on low dimensional inputs

1.1 1. Import necessary libraries and define the required classes

In [1]: %matplotlib notebook

```
import pandas as pd
import argparse
import os
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch.utils.data import Dataset, DataLoader
import pandas as pd
import time
import matplotlib
import math
from sklearn import preprocessing
from sklearn.preprocessing import normalize
# matplotlib.use('agg')
import matplotlib.pyplot as plt
import numpy as np
import collections
import random
import pickle
torch.set_default_tensor_type('torch.FloatTensor')
```

```
In [2]: ##### Multilayer fully connected network with Relu activation.
class LNN(nn.Module):
    def __init__(self, num_feature, num_hidden, nb_layers):
        super(LNN, self).__init__()
        ## Inputs:
        # num_feature: int, size of input dimension
        # num_hidden: int, number of hidden units per layer
        # nb_layers: int, number of layers
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        fc = []
        for i in range(nb_layers):
            if i == 0:
                fc.append((str(i),nn.Linear(num_feature, num_hidden)))
                fc.append((str(i)+'ReLU',nn.ReLU(inplace=True)))
            elif i == nb_layers-1:
                fc.append((str(i),nn.Linear(num_hidden,1)))
            else:
                fc.append((str(i),nn.Linear(num_hidden, num_hidden)))
                fc.append((str(i)+'ReLU',nn.ReLU(inplace=True)))
        self.linear = nn.Sequential(collections.OrderedDict(fc))
        self.log = nn.Sigmoid()

    def forward(self, x):
        # Choose whether or not to use a Sigmoid activation unit at the top of the network
        # to bound output with in (0,1)
        # x = self.log(self.linear(x))
        x = self.linear(x)
        return x

#### Training function: perform one step of accelerated gradient descent (no subsampling)
def train(net,x,y,learning_rate):
    optimizer = optim.SGD(net.parameters(), momentum = 0.9, lr=learning_rate)
    criterion = nn.MSELoss() # Using mean squared loss
    ## zero the parameter gradients
    optimizer.zero_grad()
    ## forward + backward + optimize
    outputs = net(x)
    loss = criterion(outputs, y)
    loss.backward()
    optimizer.step()
    ## Print loss
    return loss.item()

```

1.2 2. Examples:

1.2.1 a. Pneumonia age example.

```

In [3]: ##### Import Data #####
file = 'medis9847c.data' # data file
df = pd.read_table(file,header = None)
val = df.values

# extract the age feature and normalize it to within the range where most activation thr
age = (val[:,0:1]-60)/10
# extract the labels
y = val[:, -1:]

```

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##### Hyperparameters #####
num_feature = 1 # input dimension
num_epoch = 40000 # number of epoch SGD runs
num_hidden = 2000 # number of hidden units per layer
num_layer = 2 # number of layer
learning_rate = 1e-4 # learning rate

##### Experiments #####
x = age
inputs = torch.from_numpy(x).float()
outputs = torch.from_numpy(y).float()
net = LNN(num_feature, num_hidden, num_layer)
train_loss = [None]*num_epoch
for epoch in range(num_epoch): # loop over the dataset multiple times
    train_loss[epoch] = train(net, inputs, outputs, learning_rate)
    if epoch % 50 == 49:
        print('Training Iteration:', epoch+1)
        print('Training Loss:', train_loss[epoch])

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Training Loss: 0.09828850626945496
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Training Loss: 0.09350954741239548
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Training Loss: 0.09350978583097458
Training Iteration: 39950
Training Loss: 0.09350982308387756
Training Iteration: 40000
Training Loss: 0.0935092568397522

```

```

In [4]: ## Plot the results
        plt.figure(figsize = (6,6))

        plt.subplot(2,1,1)
        val = df.values
        unique_age = np.unique(age)
        h = np.asarray([np.mean(val[np.multiply(age[:,0] >= i-0,age[:,0] <= i+0),-1])+0.01 for i in unique_age])
        ## The marginalization plot p(y|x), which is the optimal predictor
        plt.plot(unique_age,h,label = 'original data')
        ## The plot of the neural net's prediction

```

```
plt.plot(unique_age,net(torch.from_numpy(unique_age[... ,np.newaxis]).float()).detach().n
plt.legend()

## Plot of training losses vs number of epoches.
plt.subplot(2,1,2)
plt.title('training loss')
plt.plot(train_loss[50:])
plt.show()
```

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

1.2.2 b. 1-dimensional dataset. Random x and y sampled from standard Gaussian. Squared loss used.

In this example, the global minimum should achieve zero training error. It seems that the neural net is trapped in some local minimum and fits a smooth function.

```
In [5]: ##### Hyperparameters#####
num_feature = 1
num_epoch = 1000000
num_hidden = 500
num_layer = 2
learning_rate = 1e-4
##### Experiments #####
num_data = 5
x = np.random.randn(num_data,num_feature)
for i in range(num_data):
    x[i,0] = 0.1*i - 0.1*num_data/2
x.sort(axis=0)
y = np.random.rand(num_data,1)
inputs = torch.from_numpy(x).float()
outputs = torch.from_numpy(y).float()
net2 = LNN(num_feature, num_hidden,num_layer)
train_loss2 = []
for epoch in range(num_epoch): # loop over the dataset multiple times
    train_loss2.append(train(net2,inputs,outputs,learning_rate))
    if epoch % 5000 == 4999:
        print('Training Iteration:',epoch+1)
        print('Training Loss:',train_loss2[-1])
```

```
Training Iteration: 5000
Training Loss: 0.07242752611637115
Training Iteration: 10000
Training Loss: 0.06980308890342712
Training Iteration: 15000
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Training Loss: 0.06843391060829163
Training Iteration: 20000
Training Loss: 0.06714524328708649
Training Iteration: 25000
Training Loss: 0.06588571518659592
Training Iteration: 30000
Training Loss: 0.06463891267776489
Training Iteration: 35000
Training Loss: 0.06340692937374115
Training Iteration: 40000
Training Loss: 0.06218086555600166
Training Iteration: 45000
Training Loss: 0.0609586238861084
Training Iteration: 50000
Training Loss: 0.059734344482421875
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Training Loss: 0.05850159004330635
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Training Loss: 0.05726361274719238
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Training Loss: 0.04907829314470291
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Training Loss: 0.04794599488377571
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Training Loss: 0.04682449623942375
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Training Loss: 0.004803562071174383
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Training Loss: 0.004787932615727186
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Training Loss: 0.004780435003340244
Training Iteration: 995000
Training Loss: 0.004773293621838093
Training Iteration: 1000000
Training Loss: 0.004766272846609354
```

```
In [8]: plt.figure(figsize = (6,6))
        plt.subplot(2,1,1)
        plt.title('label vs. prediction')
        plt.plot(x,y,'o',label = 'original data')
        plt.plot(x,net2(inputs).detach().numpy(),label = 'NN prediction')
        plt.legend()
        plt.subplot(2,1,2)
        plt.title('training loss')
        plt.plot(train_loss2)
        plt.ylim(ymin=0)
        plt.show()
```

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

```
In [9]: ## Plot the distribution of activation thresholds
        from scipy.stats import gaussian_kde
        activations = np.divide(net.linear[0].bias.data.detach().numpy(),net.linear[0].weight.data)
        density = gaussian_kde(activations)
        plt.figure()
        xs = np.linspace(-10,10,200)
        plt.plot(xs,density(xs))
        plt.show()
```

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>